JRHS 2015; 15(3): 159-162

JRHS
Journal of Research in Health Sciences
journal homepage: www.umsha.ac.ir/jrhs

Original article

Respiratory Symptoms and Pulmonary Function Tests among Galvanized Workers Exposed To Zinc Oxide

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ARTICLE INFORMATION

Article history:
Received: *13 January 2015*
Revised: *26 May 2015*
Accepted: *30 June 2015*
Available online: *02 July 2015*

Keywords:
Respiratory Symptoms
Pulmonary Function Tests
Galvanized Workers
Zinc Oxide

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ABSTRACT

Background: Galvanization is the process of coating steel or cast iron pieces with a thin layer of zinc allowing protection against corrosion. One of the important hazards in this industry is exposure to zinc compounds specially zinc oxide fumes and dusts. In this study, we evaluated chronic effects of zinc oxide on the respiratory tract of galvanizers.

Methods: Overall, 188 workers were selected from Arak galvanization plant in 2012 , 71 galvanizers as exposed group and 117 workers from other departments of plants as control group. Information was collected using American Thoracic Society (ATS) standard questionnaire, physical examination and demographic data sheet. Pulmonary function tests were measured for all subjects. Exposure assessment was done with NIOSH 7030 method.

Results: The Personal Breathing Zone (PBZ) air sampling results for zinc ranged from 6.61 to 8.25 mg/m³ above the permissible levels (Time weighted average; TWA:2 mg/m³). The prevalence of the respiratory symptoms such as dyspnea, throat and nose irritation in the exposed group was significantly (P<0.01) more than the control group. Decreasing in average percent in all spirometric parameters were seen in the galvanizers who exposed to zinc oxide fumes and dusts. The prevalence of obstructive respiratory disease was significantly (P=0.034) higher in the exposed group.

Conclusions: High workplace zinc levels are associated with an increase in respiratory morbidity in galvanizers. Therefore administrators should evaluate these workers with periodic medical examinations and implement respiratory protection program in the working areas.

Citation: Aminian O, Zeinodin H, Sadeghniiat-Haghighi K, Izadi N. Respiratory Symptoms and Pulmonary Function Tests among Galvanized Workers Exposed To Zinc Oxide. J Res Health Sci. 2015; 15(3): 159-162.

Introduction

Galvanization is the process of coating iron and steel pieces with a thin layer of zinc that causes complete protection from corrosion [1-4]. Two techniques of galvanization were done including hot dip galvanization (warm method) by passing the steel through a molten bath of zinc at the temperature of around 460 degrees Celsius. Another technique is electro galvanizing which deposits the layer of zinc from an aqueous electrolyte by electroplating. The subject of this study is warm galvanization, which has two phases. The first phase is pretreatment including the degreasing, acid pickling and fluxing. The second one is treatment in which the materials are submersed into galvanizing kettles containing molten zinc[1]. Fume exposure is the most important hazard in this industry which contains zinc chloride, ammonium and zinc oxide (ZnO), other hazards are heavy metal fumes especially zinc and hydrochloric acid vapors [2,3].

ZnO is a common constituent of particulate air pollution [6]. Environmental exposure to zinc compounds is the result of industries such as galvanization and exhaustion of vehicles tires and other sources. Acute inhalational exposure to concentrated ZnO (fume and dust) especially in welding foundry processes and galvanizing induces metal fume fever (MFF) [6]. Despite the trivial effects of MFF on respiratory function, current evidences indicate that in a long time it can causes chronic airway obstruction, for example prevalence of chronic airway obstruction in welders with repeated episodes of MFF is higher [7]. Zinc is a sensitizing agent and several cases of occupational asthma from exposure to galvanizing fumes were reported [2,7-12]. In addition, a case of urticaria and angioedema from exposure to ZnO fumes with MFF as reaction was reported[12].The other case is hypersensitivity pneumonitis from zinc fumes exposure, which pulmonary function reduction persists for long terms [13]. High ambient air particulate matter (PM 2.5) zinc levels are associated with number of asthma exacerbations and hospital admissions [14,15].

Potential health risks to workers exposed to ZnO are significant [6]. Previous studies have focused mostly on the acute effect of ZnO such as MFF on respiratory systems. Few studies have assessed the possible link between chronic lung function changes and ZnO exposures. These studies, however, were limited by lack of exposure assessment and an unavailable control group.

In the present study, we evaluated the occurrence of respiratory symptoms and chronic effect on pulmonary function in workers exposed to fumes containing zinc.

Methods

This study is retrospective cohort. The study was carried out in 2012, which was conducted in 71 male galvanizers exposed to ZnO (exposed group) and 117 male workers from other units of Arak galvanization plant (control group) which is located in the center of Iran. The length of servicing of all subjects was at least two years. All subjects were evaluated for respiratory symptoms and pulmonary function tests. Information was collected by using ATS standard questionnaire [16], physical examination and spirometric parameters including forced vital capacity (FVC), forced expiratory volume in one second (FEV1), FEV1/FVC, peak expiratory flow rate (PEFR), forced expiratory flow at 25–75% of FVC (FEF25-75) were measured. Subjects were excluded from the study if they had a history of respiratory diseases such as asthma, bronchitis, emphysema, bronchiectasis, lung cancer…or any other chronic condition in the pre-employment assessment.

The study was approved by the ethics committee of the Tehran University of Medical Sciences. Participants gave written informed consent before the study. Demographic information, history of working years, smoking habits and some questions about respiratory symptoms such as cough, sputum, dyspnea and chronic bronchitis (productive cough for two consequent years at least for three months) and throat, nose and eye burning were recorded in the questionnaire. Pulmonary function tests were carried out by a trained technician using a calibrated by spirometry apparatus (Spirolab 2), between 8-12 a.m. before starting work. A minimum of three respiratory maneuvers were taken and the best of them was taken according ATS criteria [5].

Concentration of dusts and fumes of ZnO and hydrochloric acid vapors, were measured in two different days, one month prior to the study, using NIOSH 70-30 method and with stationary and personal air sampling pumps (SKC; 2L/min) fitted with a Casella apex.

We estimated the effect size as 5 based on previous studies. Data were analyzed by SPSS 11.5 (Chicago, IL, USA). Quantitative and qualitative variables were measured. Chi square Test was used for determination of association between two qualitative variables, while independent sample *t*–test was used for evaluation difference between quantitative variables both in exposed and non-exposed groups. *P* value < 0.050 has been considered as a significant association.

Results

The concentration of ZnO in personal breathing zone (PBZ) ranged from 5.61 to 8.25 mg/m³, which all were above the permissible level (5 mg/m³). The ambient samples of ZnO yielded concentration of 3.03 to 4.46. The concentration of hydrochloric acid in PBZ sampling was below the permissible level (TLV=5 PPM).

According to Table 1, the exposed group to ZnO was younger than control group and the mean age of exposed group was 30.6 years, while for control group was 30.15, which was not significant. The mean length of service was 4.4 years in exposed group and 6.09 in control group (*P*=0.021). Smoking did not have any significant difference between two groups.

Table 1: Demographic information in exposed group (n=71) and control group (n=117)

Characteristics	Exposed	Control	*P* value
Age (yr), mean (SD)	30.6 (5.4)	33.2 (7)	0.010
Height (cm), mean (SD)	175.2 (6.0)	174.2 (6.1)	0.243
Weight (kg), mean (SD)	75.7 (9.6)	75.6 (11.5)	0.945
Length of service, mean (SD)	4.4 (2.9)	6.1 (4.6)	0.021
Smokers, n (%)	30 (42.2)	45 (38.5)	0.471

The information of clinical findings has been shown in Table 2. Accordingly, dyspnea and nose, throat and eye burning were significantly more frequent in exposed group than control group. The prevalence of sputum production tended to be higher in the galvanizer than in the control group.

Table 2: Frequency of respiratory symptoms in exposed group (n=71) and control group (n=117)

Reparatory symptoms	Exposed n (%)	Control n (%)	Odds ratio (95% CI)	*P* value
Cough	17 (23.9)	23 (19.7)	1.29 (0.58, 2.35)	0.486
Sputum	30 (42.3)	35 (29.9)	1.48 (0.80, 2.70)	0.085
Dyspnea	14 (19.7)	6 (5.1)	4.55 (1.66, 12.45)	0.002
Eye burn	37 (52.1)	38 (32.5)	2.62 (1.24, 4.15)	0.008
Nose & Throat burn	33 (46.5)	19 (16.2)	4.50 (2.30, 8.80)	0.000

The information about pulmonary function tests has been shown in Table 3. Among measured spirometric parameters (FEV1%, FVC%, FEV1/FVC, PEF% and FEF25, 75%) only FEV1% was statistically lower in exposed group than in control group.

Table 3: Pulmonary function tests in exposed group (n=71) and control group (n=117)

Spirometric parameters (% predict)	Exposed		Control		*P* value
	Mean	SD	Mean	SD	
FVC	97.80	11.93	99.92	11.40	0.227
FEV1	92.87	11.32	96.66	11.98	0.033
FEV1/FVC	79.74	6.63	80.96	6.51	0.220
PEF	95.83	12.46	98.49	14.51	0.208
FEF 25-75	78.21	22.33	84.62	23.20	0.064

The prevalence of obstructive pattern is shown in Table 4. From 71 subjects in exposed group, 15 individuals had obstructive pattern (21%) and from 117 subjects in control group 11 individuals (9%) had obstructive pattern (*P*=0.034). In each group, three subjects had restrictive pattern.

Table 4: Frequency of obstructive pattern in exposed group (n=71) and control group (n=117)

Spirometric parameters	Exposed	Control	*P* value
FEV1/FVC <75%	15	11	0.034
FEV1/FVC ≥75%	56	106	

Discussion

In this study, the workplace exposure assessment indicates that the ZnO concentration in PBZ samples was higher than permissible level in galvanizers. These are similar to Pasker et al. study, which evaluated the effect of ZnO fumes on respiratory system in a galvanization plant [17]. On the other hand, in a study carried out on health hazards evaluation in a galvanization plant, ZnO fumes concentration in PBZ samples was lower than TLV, this probably because of usage of more effective ventilation system [1].

In the present study, galvanizes developed more frequent dyspnea and upper respiratory tract irritation compared to non – galvanizers, whereas cough and sputum rate was same in both groups. Similarly, a study from Egypt found higher prevalence of exertional dyspnea among the galvanizers [4], also another study evaluated the effects of heavy metals on the respiratory system in steel plant workers and reported higher prevalence of dyspnea and sputum in this workers [18]. It is reasonable, because zinc compounds are respiratory irritants and probably can cause respiratory airway obstruction in a long term [19].

Among the spirometric parameters including FEV1%, FVC%, FEV1/FVC, PEF% and FEF 25-75% only FEV1% was significantly lower in galvanizers than non-galvanizers. However, other parameters were lower in galvanizers.

Natarajan et al. evaluated the pulmonary function in electroplaters and found significant reduction in MVV, FEF75, FEF50 and FEV1/FVC parameters [20]. Gupta et al. reported similar results in electroplaters [21].

In a study on steel plant workers, authors reported more significant reduction in FEV1/ FVC, FEF50, PIFR and SVC and higher value for RV and RV/TLC% [22]. On the other hand, safety AE and colleagues found that the spirometric parameters in galvanizers were lower than in control group but these were not significant [4]. A study including 57 exposed workers from steel plant showed the relation between the exposure of the fumes of ZnO and impairment of ventilator function. They measured spirometric parameters and reported that there were no significant difference in pulmonary function between exposed and control group [17].

In another study done in zinc, chrome and nickel electroplating plants; spirometric parameters were measured and no significant reduction in those of electroplaters was reported [23]. In this study, prevalence of obstructive pattern in exposed group was higher than the control group, which was similar to a study done in Romania, reported high prevalence of obstructive disorders in galvanizers [19]. Most studies have reported obstructive or mixed pattern from exposure to ZnO [14,17,19,20]. In our study, in galvanizers with the exposure longer than three years, the prevalence of obstructive pattern was higher than those with shorter exposure were (OR=8.1, CI = 1.7–39). This can suggest long-term respiratory effects of ZnO. Although small effects on pulmonary function were found, it is likely that they represent a subclinical response to the inhalation of low quantities of ZnO (but higher than TLV). Moreover, the duration of exposure was relatively low (in exposed group was 4.9 ±2.24), which limited the evaluation of the long time effect of ZnO exposure.

Quantitative exposure assessment, identical standardized instrument, and the same technician were used in this study. The case and control group were similar in respect to socioeconomics.

The main limitation of our study was that the differences found in respiratory symptoms and pulmonary functions between cases and controls that were at work, therefore the healthy workers' effect could have affected the current results. In addition, this study was done in one plant, so the generalizability of our results is limited.

Conclusions

The galvanizers who were exposed to ZnO fumes had more respiratory complaints. In addition, we found a significant effect on pulmonary function, which may affect the respiratory health and they are at risk of decrease of pulmonary function. It is of interest that we found statistically significant airflow obstruction (decreased FEV1/FVC ratio) with ZnO, even in workers with short-term exposures. It seems that a strong effort should be made to evaluate workers with periodic medical examinations, better ventilation should be attained, and workers should wear respiratory protective devices.

Acknowledgments

The authors thank the management, unions and participating workers of Arak Galvanization Plant for their good collaboration. This study did not have any source of financial support. The authors declare that there is no conflict of interests.

Conflict of interest statement

None declared.

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