

# Acute and Chronic Respiratory Effects of Chromium Mists

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## Abstract

**Background:** Despite wide application of chromium in electroplating industry, the pulmonary effects of chronic exposure to this chemical have not been extensively studied and are subject of debate and controversy. This study was, therefore, undertaken to further address this issue.

**Methods:** The study population consisted of a group of 15 workers with a history of past and present occupational exposure to chromium mists and 15 unexposed healthy subjects (referent). Subjects were interviewed, respiratory symptom questionnaires were filled out for them, and their parameters of pulmonary function (PFT) were measured during the shift and a few days after exposure ceased.

**Results:** Both groups were similar as to the number of smokers, their length of smoking, and demographic factors such as age, weight and height. Although the unexposed group, on average, were slightly older than their exposed counterparts, statistical analysis of the data revealed that symptoms such as productive cough, phlegm, wheezing and shortness of breath were significantly ( $P < 0.05$ ) more prevalent among the exposed workers. Furthermore, the parameters of pulmonary function (PFT) of the exposed workers, while at work, were significantly lower than those of referent individuals. Interestingly, PFT of the exposed subjects generally showed some improvement a few days after their exposure ceased. However, despite this relative recovery, the differences of PFT values between the exposed and referent groups, from statistical point of view, remained significant.

**Conclusion:** Our data support the proposition that exposure to chromium mists induces abnormal respiratory symptoms as well as both acute, partially reversible and chronic irreversible lung functional impairments.

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## Introduction

Chromium is a hard metal which is highly resistant to oxidation and is used in three basic metallurgical, chemical and refractory (heat-resistant applications) industries. The most important stable states of chromium are elemental, trivalent and hexavalent forms.<sup>1</sup> Naturally, chromium is present as trivalent.<sup>2</sup> Trivalent Cr (III)

and hexavalent Cr (VI) chromium compounds are biologically important. Trivalent Cr(III) in low doses is an essential dietary mineral for the body and Cr (VI) is 1000 times more toxic than Cr (III).<sup>3</sup> Exposure to chromium is possible through inhalation, ingestion and dermal routes.<sup>1</sup> Chronic toxic effects of chromium include effects on skin and mucous membranes, and circulatory system. Additionally, the metal is both teratogen and

carcinogen.<sup>4</sup> Factors influencing absorption of chromium following inhalational exposure include particle size, oxidation rate, solubility of chromium particles, activity of alveolar macrophages and chromium interaction with biological molecules as a result of chromium deposition in the lungs.<sup>5</sup>

Workers are primarily exposed to Cr (VI) aerosols in stainless steel welding, chromate production, electroplating and chrome pigment industries.<sup>1</sup>

The effects of occupational exposure to chromium on the respiratory system have been investigated in some studies. While in a number of studies, respiratory symptoms and a reduction in the forced expiratory volume in the first second (FEV1) in the exposed individuals have been reported, others have failed to find such an association.

For instance, Zober reported respiratory system disorders mainly in the form of acute bronchitis in chromium welders.<sup>6</sup> Additionally, Jindrichova<sup>7</sup> and Keskinen<sup>8</sup> reported that welders using electrodes containing chromium suffer from chronic bronchitis. Similar findings have been reported from German<sup>9</sup> and South Africa.<sup>10</sup>

Likewise, Subodh Kumar Rastogi<sup>11</sup> reported that the prevalence of respiratory symptoms in leather tanning workers was significantly higher than a non-exposed referent group and dry cough and throat irritation were the main respiratory symptoms in the exposed individuals. In their study, the prevalence of occupational asthma was 5%. Additionally, Lindberg and Hedenstierna<sup>12</sup> in a study on chromium electroplating industry workers concluded that forced vital capacity (FVC) and forced expiratory volume in the first second (FEV1) were both reduced by 0.2 liter and the forced mid-expiratory flow was reduced by 0.4 liter in these workers.

Transient reductions in the parameters of lung function among chromium electroplating workers have also been observed.<sup>13,14</sup>

On the contrary, US department of health, education and welfare reported that the presence of pneumoconiosis was not confirmed when 897 workers in the chromate-producing plants in the US were examined.<sup>15</sup> Similarly, Hayden<sup>16</sup> did not find any differences in the prevalence of cough and chest tightness between welders and control individuals. Moreover in a study by Riitta Erkinjuntti-Pekkanen,<sup>17</sup> annual decline in lung function was not significantly different between welders and non-welders. Similarly, Huvinen and Utti<sup>18</sup> did not find any visible radiography or respiratory changes in workers with an average exposure time of 23 years in ferrochromium and stainless steel production and low exposure to dusts and fumes including hexavalent and trivalent chromium, nickel and molybdenum.

In view of the above mentioned discrepancies, the present study was undertaken with the following objectives:

To ascertain whether long term occupational exposure to chromium is associated with any significant reductions in lung function parameters.

To find out whether exposure to chromium leads to a significant increase in the prevalence of respiratory symptoms.

## Methods

This cross-sectional study was performed in 2011 on all (15 male subjects) employees of an electroplating plant of a local telecommunication company in Shiraz. All the subjects signed an informed consent form before participating in the study. The referent group consisted of the same number of individuals whose age, sex, smoking habits and other important variables were comparable with those of the exposed group. They were selected from the staff of an educational center.

Referent subjects had no occupational or non-occupational history of exposure to chemicals known to be toxic for the lungs.

A standard respiratory questionnaire was filled out for all of the subjects.<sup>19</sup> The questionnaire contained questions regarding respiratory symptoms (chronic cough, wheezing, shortness of breath and phlegm), smoking, medical and family history (including history of chronic respiratory diseases, asthma and respiratory infections such as tuberculosis), job records and previous jobs.

Pulmonary function test (PFT) was performed according to the guidelines given by the ATS<sup>20</sup> and measured with a portable calibrated vitalograph spirometer (Vitalograph-COMPACT, Buckingham-England) on site, twice for the exposed subjects (at the beginning of the shift following a 48 hour exposure free period and at the end of the week) and once for the referent individuals.

The measured parameters included mean percentage predicted vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in the first second (FEV1) and peak expiratory flow (PEF). The mean percentage predicted value was based on the subjects' age, weight, standing height, sex and ethnic group as calculated and adjusted by spirometer device.

The data were statistically analyzed using the Student's t-test and Chi-square or Fisher's exact test, where applicable. In all the statistical comparisons, a p value of less than 0.05 was considered significant. Experimental (descriptive) results are presented as arithmetic means  $\pm$  SD. Statistical tests were

conducted using InStat software.

## Results

Table 1 presents demographic characteristics, smoking habits of both exposed and non-exposed groups. As shown, no statistically significant differences were noted in the mean value of these parameters between both groups ( $P>0.05$ ).

Table 2 illustrates the frequency of respiratory

symptoms among the exposed and non-exposed subjects. As shown, the prevalence of regular cough, wheezing, breathlessness, chest tightness and respiratory tract irritation was significantly higher in the exposed subjects than in the referent subjects.

Table 3 illustrates the results of lung function tests for the studied subjects. As shown, both baseline and end of week values of most parameters of pulmonary function of the exposed employees were significantly lower than those of the referent subjects.

**Table 1:** Physical and demographic characteristics of the exposed and non-exposed subjects

Parameter	Exposed (n=15) Mean±SD	Non-exposed (n=15) Mean±SD	P value
Age (year)	36.20±9.51	37.80±9.91	0.32
Minimum-Maximum	24-49	25-54	
Weight (Kg)	74.73±15.46	67.46±10.50	0.14
Minimum-Maximum	42-97	45-84	
Height (cm)	172.33±9.43	172.53±4.94	0.94
Minimum-Maximum	150-185	168-183	
Length of employment (year)	8.93±7.23	8.40±6.70	0.78
Minimum-Maximum	1-22	1-24	
Length of smoking (year)	22.66±9.71	18.33±2.08	0.49
Minimum-Maximum	0-31	0-26	
Smoking			
Yes	3	3	0.67
No	12	12	

\*Student's T-Test

**Table 2:** Frequency (%) of respiratory symptoms in the exposed and non-exposed subjects

Parameter	Exposed N (%)	Non-exposed N (%)	P value	Odd ratio
Cough	8 (53.33)	1 (6.70)	0.01	16
Phlegm	6 (40)	3 (20)	0.42	2.66
Wheezing	13 (86.70)	3 (20)	0.0007	26
Breathlessness	10 (66.70)	1 (6.70)	0.001	28
Chest tightness	11 (73.33)	1 (6.70)	0.005	38.50
Irritation of throat	5 (33.33)	1 (6.70)	0.16	7
Respiratory tract irritation	7 (46.70)	1 (6.70)	0.03	12.20

\*Fisher Test

**Table 3:** Percentage predicted lung function for the exposed and non-exposed workers

Parameter	Exposed (n=15)		Non-exposed (n=15)	P value (before shift vs end of the week)	P value (before shift vs referent)	P value (end of the week vs referent)	Mean difference (end of the week and Non-exposed)
	Before shift	End of the week					
VC	74.93±15.72	60.46±14.67	88.20±8.36	<0.0001	0.003	<0.0001	-27.73
Minimum-Maximum	47-108	37-86	78-113				
FVC	79±19.40	70±14.13	86.86±5.78	0.003	0.07	<0.0001	-16.86
Minimum-Maximum	55-124	51-102	76-96				
FEV1	80.53±17.81	73.33±14.78	90±6.84	0.005	0.02	<0.0001	-16.67
Minimum-Maximum	53-134	40-102	72-98				
FEV1/FVC	105.06±19.88	102.04±18.26	104.46±5.26	0.37	0.39	0.42	-2.42
Minimum-Maximum	66-137	53-126	95-114				
PEF	67.53±18.89	56.93±14.77	83.60±23.27	0.001	0.02	0.0006	-26.67
Minimum-Maximum	36-112	34-80	43-127				

\*T-Test

Additionally, significant decrements were noted in mean values of VC, FVC, FEV1 and PEF parameters in the exposed group at the end of the week compared to their corresponding pre-shift values.

## Discussion

The aims of this study were to evaluate possible pulmonary reactions associated with occupational inhalation exposure to mists of hexavalent chromium in an electroplating plant. Given the data provided, there were no significant differences in the major confounding variables of age, weight, height, length of employment and smoking habits between the exposed and unexposed groups (Table 1). Additionally, none of the subjects had past medical or family history of respiratory illnesses or any other chest operations or injuries. Therefore, increased prevalence of respiratory symptoms and significant PFT changes may well be attributed to exposure to hexavalent chromium.

Only a small proportion (20%) of subjects were smokers and their distribution among both groups was uniform. Moreover, no significant differences existed in the number of smokers and their length and severity of smoking in both groups. This rules out the role of cigarette smoking as a potential confounder in the overall findings of the study and further confirm this conclusion.

Prevalence rates of respiratory symptoms such as cough, wheezing, breathlessness, chest tightness and respiratory tract irritation in the exposed subjects were significantly higher than those of the referent group.

Consistent with these findings, Faridah and colleagues (2011)<sup>21</sup> investigated the effects of nickel and chromium on the respiratory system of 233 male workers and showed that 26.6% of production workers had a respiratory disease which was associated with wheezing, shortness of breath and sneezing attacks.

Furthermore, Nurul Ainun Hamzah and colleagues<sup>22</sup> studied 402 steel plant workers and reported that increased cumulative exposure to chromium dust was accompanied by increased prevalence of respiratory symptoms. Additionally, Faridah and colleagues in 2013<sup>23</sup> studied 40 tannery workers and reported that the respiratory symptoms among them were significantly higher than those of a control group and the most prevalent respiratory symptoms were shortness of breath, wheezing and cough.

In contrast, Huvinen and colleagues<sup>18</sup> followed 203 stainless steel workers over a five year period (from 1993 to 1998). They did not observe any adverse respiratory effects in a group of workers exposed to hexavalent chromium when compared with a control group.

The distinction between acute and chronic effects of exposure to chromium has not previously been

thoroughly investigated. In the present study, in order to differentiate these effects, the parameters of pulmonary functions were measured twice, before the shift, following a 48 hour exposure-free period, and at the end of the week, after 5 consecutive days of exposure.

As shown in Table 3, statistically significant decrements were noted in most parameters of pulmonary function after exposure. When exposure to chromium mist temporarily ceased, partial recovery in PFTs was noted. These results are thought to support the hypothesis that exposure to chromium is associated with acute, partially reversible decrements in the lung's functional capacities.

Interestingly, despite this relative recovery, the mean values of most parameters of pulmonary function of the exposed employees were significantly lower than those of the referent subjects. This observation indicates that chromium also induces chronic irreversible ventilatory disorders.

Similar findings on the chronic effects of chromium have been reported by other investigators. For instance, Hsien-wen Kuo and colleagues<sup>24</sup> studied 189 workers from 11 electroplating factories and showed lower FEV1, FVC and VC values compared to workers of a zinc factory. Additionally, Osim and colleagues<sup>25</sup> studied 54 chromium mining workers and 50 control subjects. They reported significant decrements in FVC, FEV1 and PEF values of mining workers as compared with the control group. Furthermore, Nurul Ainun Hamzah and colleagues<sup>22</sup> reported significant negative correlations between FEV1 and FVC values and cumulative exposure to chromium dust. Similarly, Amal Saad-Hussein and colleagues<sup>26</sup> reported significant reductions in FEV1 and FVC values of leather workers exposed to chromium compounds.

In contrast, in a study conducted by Sobaszek and colleagues<sup>27</sup> on 134 stainless steel workers, the authors did not observe any significant differences in the parameters of pulmonary function of the exposed employees as compared to a the non-exposed referent group. Similarly, Antti-Poika and his colleagues failed to find any significant differences in the lung function parameters of the chromium exposed workers and the non-exposed group.<sup>28</sup>

The exact reason(s) of these discrepancies are not known. However, differences in exposure scenarios, both in terms of length and severity of exposure, use of respiratory protective equipment and selection bias may explain, at least in part, these discrepancies.

A cause and effect relationship cannot be established from cross-sectional studies such as the present one. Therefore, one might speculate that findings of the study may not necessarily be attributed



to exposure to hexavalent chromium.

In response, it has to be reiterated that the following few lines of circumstantial evidence indicate that these outcomes are very likely to be the consequence of exposure to chromium:

First, the exposed subjects, when employed, were free from any preexisting medical conditions, particularly those of respiratory symptoms.

Second, the exposed individuals had no history of exposure to other chemicals known to cause respiratory disorders prior to their employment in the plant.

Third, despite the fact that the non-exposed subjects were slightly older (on average 1.6 years) than their exposed counterparts, respiratory symptoms were significantly more prevalent in the exposed group than in the referent subjects and their ventilatory capacities were significantly lower.

Fourth, although the exposed subjects experienced some improvement in their PFTs following temporary cessation of exposure, differences for most parameters of pulmonary function between the exposed and non-exposed employees remained significant (Table 3).

## Conclusion

In conclusion, the findings of this study further support the contention that occupational exposure to hexavalent chromium mists is associated with increased prevalence of respiratory symptoms and lung functional (acute partially reversible and chronic irreversible) impairments. However, given the inevitable small sample size of the study and absence of quantitative exposure data, additional prospective studies with larger sample sizes in which exposure is accurately quantified are clearly required to further support our findings, particularly the observed acute effects.

**Conflict of Interest:** None declared.

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