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Lung Health Among Welders

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Abstract

Background: Iron and steel based industries use welding as an integral process. About two percent of the working population is engaged in some type of welding. Welding fumes consist of a wide range of complex metal oxide particles which can be deposited in all regions of the respiratory tract. Thus, welding process seems to be simple but its health implications are complex. Materials and methods: In the present paper, various studies from various databases, based on the health effects of welding fumes have been reviewed to summarize the effect of welding fumes on the lung health. Results: Different studies have shown the ill health effects of welding fumes on the respiratory system of workers engaged in welding industry. Welding fumes have been found to show deleterious effects resulting in serious health hazards including cancer. Conclusion: Workers engaged in welding industry are advised to modify their lifestyle and working methods. They should use proper protection equipments so as to minimize the exposure to different gases and fumes produced as a result of welding process.

Keywords

Welding Fumes, Lungs, Welders, Particles, Metals, Cancer, Metal Fume Fever

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1. Introduction

Iron and steel industry is one of the leading industries in the world. Lakhs of workers are employed each year for different types of jobs in these industries. Welding is one of the key components of numerous manufacturing industries, which pose potential physical and chemical health hazards. Welders are exposed to a number of genotoxic metals, gases, fumes and radiations [1, 2]. Welding fumes consist of a wide range of complex metal oxide particles which can be deposited in all regions of the respiratory tract and may cause inflammation [3]. The welding aerosol is not homogeneous and is generated mostly from the electrode wire. Welding procedures may result in the production of various gases (metal oxides, CO_2, CO, O_3, NO_2, hydrocarbons) and welding fumes. According to OSHA, the welding fume may contain manganese (Mn), beryllium (Be), cadmium (Cd), chromium (Cr), vanadium (V), antimony (Sb), zinc (Zn), nickel (Ni), molybdenum (Mo), mercury (Hg), lead (Pb), iron (Fe) and cobalt (Co). The chemical composition of the welding fumes depends upon various factors like type of welding, metal coating, material of the electrode and type of metal being weld. Welding fume pulmonary effects have been associated with bronchitis, metal fume fever [4], cancer [5] and functional changes in the lung. Welders are exposed to a variety of metal fumes, including manganese [6, 7] that may elevate the risk for neurological diseases [8, 9]. Biological monitoring of occupational exposure to toxic compounds enables an early detection of adverse health effects.

Welders are a class of workers who are exposed to a number of nascent metals and fumes. Welding fumes containing oxides of nitrogen and ozone can cause irritation and may result in metal fume fever. The risk to the worker depends upon the process, the type of metal used, the rod and the flux, and contaminants on the surface. The prolonged exposures to

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welding fumes may lead to lung diseases and increase the risk of occupational asthma and even cancer [10]. Welders are particularly prone to a lung infection that can lead to severe and sometimes fatal pneumonia also. Irritation of throat and lungs and temporary reduced lung function may also occur. Thus, an attempt has been made in this paper to summarize the health implications of the welding fume exposure to the workers engaged in welding procedures. This paper will also help to create awareness about the health impacts of welding fumes, importance of improved working methods and safe industrial environments.

2. Effects of Welding Fumes on Lungs

Welders experience bronchitis, metal fume fever, lung function changes and an increase in the incidence of lung infection [11]. By taking the model of Male Sprague-Dawley rats, a study assessed the early effects of stainless steel (SS) welding fume inhalation on lung injury, inflammation, and defense responses. Rats were exposed to gas metal arc-SS welding fume at a concentration of 15 or 40 mg/m^3 x 3 h/day for 1, 3, or 10 days. The control group was exposed to filtered air. At 1, 4, 6, 11, 14, and 30 days after the final exposure, parameters of lung injury including lactate dehydrogenase and albumin; and inflammation (Polymorphonuclear leukocyte- PMN influx) were measured in the bronchoalveolar lavage fluid. Parameters of lung injury were found to be significantly elevated at all-time points post-exposure compared to controls except for 30 days. Thus, a short-term exposure of rats to SS welding fume was found to cause significant lung damage and suppressed lung defense responses to bacterial infection, but had a delayed effect on pulmonary inflammation [11]. Similarly, in an another study on rats, Antonini et al. [12] determined if freshly formed welding fume induces greater lung inflammation and injury in rats due to the presence of reactive oxygen species than aged welding fume. Fume was collected during gas metal arc welding using a stainless steel consumable electrode and was found to be of respirable size. More neutrophils and enhanced glucosaminidase (GLU) activity were observed for the 'fresh' group as compared to 'aged' groups ($P < 0.05$). Thus, the study demonstrated that freshly generated stainless steel welding fume induces greater lung inflammation than 'aged' fume. This is likely due to a higher concentration of ROS on fresh fume surfaces [12]. Another study assessed the effect of inhalation exposure to mild steel (MS) welding fume on lung injury, inflammation, and defense responses. Male Sprague-Dawley rats were exposed to MS fume for 3 or 10 days using a robotic welding fume generator. No significant difference was observed in lung injury or inflammation after MS fume inhalation at 1, 4, and 11 days after the last exposure. However, there were significantly more bacteria at 3 days after infection in the lungs of the animals exposed to MS fume compared to air controls [13].

Pulmonary function and gene-expression profiles in the lung were analyzed by Affymetrix Gene Chip microarray after 30 days of consecutive exposure to manual metal arc welding combined with stainless-steel (MMA-SS) welding fumes, and again after 30 days of recovery from MMA-SS fume exposure. In total, 577 genes were identified as being either up-regulated or down-regulated. Several genes that might play a role in the repair process of the lung were found to be up-regulated exclusively in the recovery group [14]. Another study examined acute lung damage and inflammation, as well as free radical production, caused by welding fumes of different chemical compositions and solubilities. The fumes were taken from a gas metal arc welding using a mild-steel (GMA-MS) or stainless-steel electrode (GMA-SS) and a manual metal arc welding using a stainless-steel electrode (MMA-SS). MMA-SS was the only fume to contain soluble chromium. All of the fumes increased the cytotoxicity. Both the soluble and insoluble fractions of the MMA-SS fume were required to produce most effects, indicating that the responses are not dependent exclusively on the soluble metals [15].

3. Particle Retention and Clearance

Stainless steel welding fumes produced by manual metal arc and metal inert gas (MIG) techniques were found to be dissolved in rat lungs. The particles of the principal population (size 100-250 nm) were found to be dissolved in both alveolar macrophages and type 1 epithelial cells in about two months. But, the particles of the minor population (size 5-100 nm) showed no signs of dissolution during three months follow up [16]. After initial rapid clearance of deposited material from the lungs, persistent residual deposits remain in the lungs [17]. In another study, widespread but small deposits of fume particles were found to be cleared effectively from alveoli and airways but peri-bronchial and sub-pleural aggregates of particle-laden macrophages remained there [18]. Persistent lung-burdens were established by intra-tracheal administration of suspensions of fume-particles (10 mg and 50 mg, single doses). These particles caused alveolar epithelial thickening, with proliferation of granular pneumocytes and exudation of lamellar material. Giant cells were also formed and nodules containing MIG-SS material were irregular and surrounded by collapsed and thickened epithelium [18]. Similarly, another study indicated that the lung retention and clearance patterns for the two types of welding fumes (manual metal arc stainless steel and mild steel welding fumes) were different. A linear relationship was observed between the amount of stainless steel MMA welding fume retained in the lungs and the duration of exposure, whereas the retention of mild steel MMA welding fume in the lung was saturated as a function of the cumulative exposure time rates [19].

4. Welding Fumes and Lung Cancer

Welding fumes are known to contain certain metals which can cause serious health hazards including cancer. Different studies by a number of authors have been conducted to find out the association of welding fumes with cancer [20-25]. Stainless steel welding is associated with exposure to metals including hexavalent chromium and nickel. The calculated pooled relative risk estimate was found to be 1.94 with a 95% confidence interval of 1.28-2.93 and it suggested a causal relation between exposure to stainless steel welding and lung cancer [26].

Mutations of suppressor gene p53 was studied in 36 cases of silica related lung cancer and 6 cases of welding fume related lung cancer with immune-histochemical and PCR- Single-strand conformational polymorphism (SSCP) methods. Gene mutation frequency in varied pathological categories of pneumoconiosis related lung cancer was found to differ from that in common lung cancer where the highest one was in small cell lung cancer (70%) and the lowest in adenocarcinoma (33%) [34]. A meta-analysis showed a 26% excess of lung cancer for welders without any difference according to welding activities [20].

Table 1. Studies on cancer incidences among workers engaged in welding.

Sr. No.	Study	Workers	Findings
1.	Danielsen et al. [27]	4480 shipyard workers including 861 welders	Nine cases of lung cancer were found among the welders versus 7.1 expected. Welders with the longest experience had a relative risk of 1.9 for lung cancer.
2.	Becker [28]	1213 welders and 1688 turners (control)	An elevation of approximately 50% or 60% in mortality from cancers of the respiratory tract.
3.	Danielsen et al. [29]	428 shipyard welders exposed >10 years to welding fumes	32 cases of cancer from all causes Vs. 41.3 expected. Incidence of lung cancer was highest for the welders with more than 30 years since first exposure.
4.	Moulin [30]	Shipyard, mild steel, and stainless steel welders	A 30-40% increase in the RR of lung cancer among welders. Asbestos exposure and smoking may account for the same.
5.	Lauritsen and Hansen [31]	8,372 metal workers	70% excess of lung cancer associated with "welding exposure ever". The risk estimates showed increasing tendency up to 15 years of exposure.
6.	Hansen et al. [32]	10,059 metal workers	Significant excess risk of lung cancer among "mild steel only welders" and "non-welders"; a borderline significant lung cancer excess among "MS ever welders"; employment as a welder is associated with an increased lung cancer risk.
7.	Danielsen et al. [33]	2957 boiler welders	An excess of lung cancer was found; 50 cases Vs. 37.5 expected. Excess risk did not seem to be associated with SS welding. Smoking and asbestos exposure were potential confounders.

RR, Relative risk; SS, Stainless steel

Another study corroborates the findings that welders have an increased risk of lung cancer. While exposure-response relations indicated carcinogenic effects related to stainless steel welding [35]. Matrat et al. [36] investigated the relationship between lung cancer and occupational exposure to welding activity in ICARE, a population-based case-control study. The results revealed that type of welding and mode of workpiece preparation are important determinants of the lung cancer risk in regular welders. Our previous studies [37-40] also showed an increase in the genetic toxicity and oxidative stress in welders which may lead to cancer.

5. Conclusion

Welders are a class of workers who are exposed to a number of gases, nascent metals and fumes. These exposures cause serious health hazards among welders. Studies have shown that welders are prone to an elevated risk of different health ailments including respiratory problems like asthma, bronchitis and pneumonia; neurological disorders and even lung cancer. Thus, welders should take proper protection measures to reduce the exposure to different gases and fumes emitted during the welding proceduresby using proper protection equipments.

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