What Do We Know Today about Welding-fume Effects on the Respiratory System?

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Abstract: The purpose of this review of the last ten years' publications was to show our present knowledge about welding-fume effects on the respiratory system. Welding generates particles and gases which are characteristic for the method used and the material welded. Various investigations to determine if respiratory system diseases occur more often in welders than in others not exposed have yielded diverging results. One explanation of this may be that the exposure of welders in the various studies may not be directly comparable and the majority of authors did not take into consideration the impact of other conditions of the working environment. This review represents all known respiratory symptoms, like siderosis, chronic bronchitis, fibrosis of lung, asthma, lung cancer and diseases of the upper respiratory tract, which can occur in welders. Furthermore are given the legal base for declaration of these diseases as an occupational disease and the fitness rules for welders in GDR.

Key words: Respiratory symptoms in welders—Siderosis—Chronic bronchitis—Fibrosis of lung—Welding fumes

INTRODUCTION

Welding as a technology of joining metals by fire has already been used in former times. The detection of new possibilities of joining metals in the last two decades of the 19th century and the development of various welding processes throughout the 20th century led to an universal application of this technology in many countries.1

The first reports on health hazards caused by welding-fumes, already given in 1938, were about pneumoconiosis in welders, which was then considered to be a harmless deposition of iron-dust without any health impairment.2

In the last 20 years, the number of reports on health hazards in welders
increased. Most observations made were of respiratory symptoms, because the welder inhales particular fumes and gases, which are produced in various welding processes. These symptoms range from pneumoconiosis (siderosis pulmonum) to lung cancer, given as single-case reports as well as epidemiological studies with different interpretations of their findings. Therefore, the author wants to show our present knowledge about welding-fume effects on the respiratory system in a review of the last ten years’ publications.

**Welding Techniques**

The most common welding process is manual metal arc welding (MMA), performed with hand-held electrodes known as rutile and basic electrodes depending on their coating materials.

In tungsten inert gas welding (TIG) a tungsten electrode is protected from oxidization by an inert gas shield. Other shielding gas welding processes are the so-called metal inert gas welding (MIG) and metal active gas welding (MAG). Besides these, there are a number of other special technologies which are not as common as those mentioned above.

The preferably used material is mild steel (MS), but stainless steel (SS) and alloys containing nickel, chromium or other components and aluminium are also welded. Each welding technique and application produces a characteristic composition of fumes and gases with metallic and non-metallic components.

So, for example, if mild steel is welded, fumes in MMA consist of Fe, Mn, Si, Na, Ca, F (for further details see\(^3,4,31\)).

**Respiratory Symptoms**

1. **Pneumoconiosis**

   Reticular shadows and/or micronodular opacities (p/q, according to the classification ILO 1971) are the X-ray abnormalities, which most authors found in welders.\(^5-8\)

   These shadows are localized in the lower and lateral parts of the lung. Macronodular opacities are not typical for siderosis; other diseases have to be excluded.\(^6\)

   The prevalence of siderosis pulmonum increases according to the duration of employment (with a minimum of ten years).\(^5-10\) It does not depend on other factors like age and smoking habits.\(^7\) But Shima et al.\(^32\) reported that the development of siderosis in welders with less than ten years’ exposition is also possible. A remarkable number of their patients were young workers. Siderosis pulmonum is very often a casual finding in X-ray examinations, because the deposition of iron-oxide dust in the tissue causes no respiratory symptoms and no decrease in ventilatory function.\(^5,8,11\)

   Pneumoconiosis progress and development of concomitant chronic bronchitis
were favoured if the worker did not give up his work. In patients who changed their job, pneumoconiosis did not progress or regressed. Older authors did not observe significant changes in X-ray pictures when the job was continued. Depending on technology, most findings of pneumoconiosis were made in MMA, whereas roentgenological findings of siderosis in MIG and TIG welders are not so frequent.

Examinations of ventilatory function in welders with siderosis did not reveal an increased prevalence of a decrease of ventilatory function in comparison with workers without welding-fume exposition. If pathological findings of ventilatory function are expected, special examinations should be carried out, especially with regard to a change of employment in order to avoid a further deterioration.

2. Chronic bronchitis and ventilatory function

Chronic bronchitis is a common disease in professionally exposed and professionally non-exposed people of industrialized countries. Therefore, the establishment of criteria of evaluating chronic bronchitis as an occupational disease is very difficult. The results of epidemiological studies are the basis of such criteria. Unfortunately, only a few of these studies are concerning chronic bronchitis and ventilatory function in welders. This article is informing about the results of some of these studies. In a GDR-study in 9 different factories (ship-building, chemical engineering, agricultural engineering) the authors found twice the number of welders with bronchitis compared to non-exposed groups.

On the other hand, ventilatory function indices like FVC and FEV₁ showed no significant difference compared to a control group. This effect illustrates the influence of smoking i.e. it exists in the same way in smokers, ex-smokers and non-smokers. Smoking alone causes a treble increase in chronic bronchitis.

On the contrary, parameters of small airways, ventilatory distribution and bronchial reactivity often suggest a trend towards worse average in welders.

Another epidemiological study with a group of 346 welders compared to a group of 214 non-welding workers discusses the following results: Bronchitis and dyspnoea were encountered more frequently in manual welders. Chronic bronchitis tended to be more frequent among welders working in closed rooms and in those welding stainless steel. Furthermore, the ventilatory function of welders is similar to that of control non-welders. Smoking is regarded as a “confounding factor”. The authors wrote that “the typical ‘welder at risk’ would be the one smoking more than 20 cigarettes per day and doing manual welding for more than ten years”.

Other authors who also examined large groups of welders pointed out that there is no statistically significant correlation between chronic bronchitis and age, smoking habits and time of exposure. And in consideration of lung function tests there does not exist any correlation between lung function and smoking habits. In another study among 83 stainless steel welders the authors wrote
that the prevalence of symptoms of chronic bronchitis depended only on smoking. Furthermore, it was recognized that conventional spirometric indices (VC, FEV₁, FEV %) are not sensitive enough to detect changes in small airways.¹⁶)

In 432 electric welders and 420 workers not respiratory exposed, the information value of spirometry (VC, FEV₁) and flow volume graphs (PEF, \( \dot{V}_{2}/\dot{V}_{15}, \dot{V}_{50}, \dot{V}_{75} \)) were examined. The authors could show that welding-fumes did not have any influence on the above mentioned parameters in exposed workers. Therefore, a wider use of flow volume graphs in the screening of non-selected groups of different exposure cannot be supported.¹¹)

3. Fibrosis of lung
In 1975, Irmscher et al.¹⁷) published first criteria of lung-fibrosis as an occupational disease in welders.

They established the following criteria:

a. Evidence of a long exposition of welding-fumes in high concentration, especially if welding was performed in closed rooms without exhaust.

b. Roentgenological or histological evidence of FeO-deposition in the lung as an argument proving a fundamental welding-fume exposure.

c. Histological evidence of interstitial fibrosis.

d. Absence of non-occupational factors which cause fibrosis of lung.

And in 1984 Stanulla et al.⁴) informed in a clinical study about histologically examined lung-tissue proofs in 36 MMA welders obtained by mini-thoracotomy. They found a focal siderofibrosis in all the proofs. It is important that there was no diffuse but always local fibrotic reaction in connection to the FeO-depositions.

As a result of a review of publications up to 1979 Zober¹⁸) wrote that fibrosis appears after long occupational exposure (average 21 years) and that the welders worked in narrow rooms without adequate ventilation. More than the fourth part of the workers had broncho-pulmonary disease in anamnesis referring to disturbance of lung-clearance mechanism. Further this author wrote: “In relation to the number of persons in this occupation (more than 200,000 in West Germany alone), pulmonary fibrosis is a rare event in electric welders.”¹¹³)

4. Occupational asthma
Only a few authors wrote about occupational asthma due to welding-fumes. So Keskinen and Kalliomäki⁵) pointed out that the findings of four stainless steel MMA welders suggested the possibility of occupational asthma. Most authors regard chromium or nickel, which are emitted from Cr-Ni-coated electrodes, as the cause of occupational asthma in welders.⁵) The role of metal allergens in the development of bronchospasm has to be confirmed by means of inhalation tests with the adequate metals.¹²,¹³)
5. **Lung cancer**

In a retrospective follow-up study among chromium and nickel exposed welders Becker *et al.*\(^{19}\) pointed out an increased cancer risk in comparison with a reference group. This finding is explained by the fact that the percentage of hexavalent chromium compounds in the welding-fumes of coated electrodes is higher than in other welding processes.

Other authors such as Gobatto *et al.*,\(^{20}\) Stern\(^{21}\) and Bergmann,\(^{28}\) according to their findings, agree that welding-fumes may cause a higher risk of lung cancer.

In contradiction to the above mentioned authors, Zober\(^{13}\) wrote that "welding fumes generally do not have an increased cancer risk". Only welding with coated Cr-Ni-electrodes may be a factor of risk increase. The confounding factor asbestos in former expositions (see Sandén\(^{20}\)) and the small number of lethal cases do not allow any final statements about an increased cancer risk in welders.

An interdisciplinary conference held in 1985 in Copenhagen concludes that "retrospective cohort studies of both stainless steel and other welders who have been exposed for many years and followed up for at least 20 years are therefore urgently needed."\(^{26}\)

6. **Diseases of the upper respiratory tract**

Werner,\(^{22,23,34}\) an otorhinolaryngologist examined 75 MMA welders and 127 steel-construction fitters with and without welding functions. In the group of welders she found severe chronic inflammations of the upper respiratory tract (chronic rhinitis, pharyngitis, laryngitis). Most of the welders suffered from chronic rhinitis (39% hyperplastic and 41% atrophic forms). The steel-construction fitters with more than 4 hours welding-time a day showed the same symptoms, whereas the group without welding-functions or with less than 2 hours welding-time a day had no signs of chronic inflammation. Some of the welders suffered a loss of the sense of smell, whereas a loss of the sense of taste was never observed. The roughness of welders' voices should also be noticed as a symptom. In his study Kalliomäki\(^{16}\) observed that chronic rhinitis was the most prevalent symptom in stainless steel MMA welders and that these welders tended to experience more irritation in the upper respiratory tract than stainless steel TIG welders. And Åkesson\(^{24}\) reported upon an examination of 11 high nickel alloy welders. Subjective complaints of irritation of respiratory tract (nose, nasopharynx, bronchi) and eye irritation were more prevalent in welding high nickel alloy than in welding stainless steel. The findings of Jindrichova\(^{25}\) are also remarkable. In 36% of a group of 11 welders who worked with chromium-coated electrodes in 70% of their working hours she detected defects of the nose septum. Furthermore, these welders showed atrophic rhinitis, pharyngitis and chronic laryngitis. Gola\(^{29}\) examined 73 workers who mainly performed electric arc welding. Most of them noticed acute rhinitis, cough and expectoration during work.
LEGAL ASPECTS OF DECLARATION AS OCCUPATIONAL DISEASE

In the GDR, in special cases the legal recognition as an occupational disease is possible on the following conditions:

1. chronic bronchitis with abnormal results in pulmonary function which can be reproduced;
2. siderosis of lung with disorders in pulmonary function (e.g. decreased diffusing capacity);
3. fibrosis of lung (for criteria see part 3);
4. chronic diseases of upper respiratory tract after confirmation by an otorhinolaryngologist.

This legal recognition can be achieved in a special procedure called “Sonderentscheidverfahren”.27)

Similar criteria for a legal recognition are also applied in the FRG. For instance they were reported by Zober.13)

To prevent the emergence or deterioration of already existing diseases by welding-fumes, the following fitness restrictions are recommended:30,35) bronchial asthma, chronic bronchitis, rhinitis vasomotorica, chronic inflammations of the upper respiratory tract, pneumoconiosis and other lung diseases with decreased ventilatory function, diseases of the bony thorax and thoracic deformities.

CONCLUSIONS

The examples given show that the severity and prevalence of respiratory effects among welders vary in the different defined groups of welders. Furthermore, in several studies there was little difference between welders and control groups. This reflects the heterogeneous conditions of exposure in the different welding technologies. Technological parameters of welding (e.g. welding process, used adding and parent metal) are important for the evaluation of a possible health risk, because the quantity of produced welding-fumes depends on the adding metal (e.g. electrode-coating). Besides these factors, the majority of authors did not take into consideration the impact of other conditions of the working environment on the health of welders. Therefore, it is very difficult or even impossible to generalize the various reported findings. The existence of a clinical picture “welder's lung” seems not to be evident.

Until today the following questions remain unanswered:
—What is a safe level of welding-fume concentration at the work place without producing any health risk?
—Are there other factors which, in particular cases, cause or favour an unfavourable development?
—Will bronchopulmonary diseases in welders get better after a change of work place, if so, when would be the right moment for it?
Therefore, further follow-up and retrospective cohort studies which take into consideration technological parameters and other influences of the working environment on the respiratory system should be carried out in order to answer the above mentioned questions.

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