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Breathe Safe

Welding Fume Risks

Contents

Introduction

There are approximately 80,000 welders in the UK and 11 million worldwide. A further 110 million workers worldwide are exposed to welding [3]. Welding fume be dangerous. Its association with lung cancer in particular has been widely studied. There is also strong evidence of its correlation with other cancers, as well as some evidence of association with Parkinson's disease and parkinsonism. In addition, there are acute health risks, such as irritation to the throat and larger airways in the lungs, acute pneumonia, metal fume fever, and acute irritant-induced asthma, formerly known as 'Reactive Airways Dysfunction Syndrome', or RADS [2].

As early as 1936, iron deposits were discovered in the lungs of an arc welder and the case was described in *The Lancet* as pneumosiderosis or Welder's lung [8]. In 1989, the International Agency for Research on Cancer (IARC), part of the World Health Organisation, evaluated welding as "possibly carcinogenic to humans" (Group 2B). This was based on 'limited' evidence from human beings and 'inadequate' evidence from experimental animals [4]. The IARC classified welding fumes and ultraviolet (UV) radiation from welding as carcinogenic to humans (Group 1) in 2018 [3].

The Health and Safety Executive (HSE) is the UK government agency responsible for the encouragement, regulation and enforcement of workplace health, safety and welfare, and for research into occupational risks. In 2019, it reclassified welding fume, including welding fume from mild steel welding, as a carcinogen and revised its guidance for workers' protection. It also classifies chromium, present in much welding fume, as an asthmagen [37].

The techniques the HSE recommends for protecting workers from fume include: "eliminating welding where possible by using cold joining techniques with mechanical fasteners or adhesives." If welding cannot be eliminated it recommends "reducing the amount of welding, using a consumable that produces less fume, using a welding process that produces less fume, making sure the metal has been properly cleaned and prepared, automating or mechanising the process or job, or using other engineering controls such as LEV [local exhaust ventilation]" [24]. In addition, it recommends respiratory protective equipment (RPE), such as "an FFP3

disposable mask or half-mask with P3 filter (PDF), for work of up to an hour, or a battery-powered air-fed protective equipment for longer duration work, with a minimum assigned protection factor of 20 (APF20), and to ensure RPE wearers are clean shaven and provide face-fit testing for them" [34].

The types of welding

There are over 30 types of welding which produce different amounts and types of fume.

Arc welding is the most common type of welding. It comes in many different types, some of which are:

- Gas Metal Arc Welding (GMAW/MIG)
- Gas Tungsten Arc Welding (GTAW/TIG)
- Shielded Metal Arc Welding (SMAW/MMAW)
- Submerged Arc Welding (SAW)
- Plasma Arc Cutting (PACW)
- Flux Core Arc Welding (FCAW)

Other types of welding include Electric Resistance Welding (ERW), widely used in the assembly of steel pipes and automobiles and solid-state, and pressure welding which does not involve the application of heat. Less commonly, oxy-fuel welding and cutting techniques are used although these have largely been superseded by the arc welding techniques above.

Types of fume

In welding, temperatures above 5,000℃ melt the joint and filler material between two pieces of metal. An electric arc is established between the workpieces and a consumable wire electrode. From this, welding fume is produced. This consists of tiny particles 0.01 µm - 20 µm in size with a median size of 0.2 - 0.5 µm. Fume is composed of particles of vaporised metal oxides and the consumable wire electrode [1].

Different types of welding techniques and different metals being worked on produce different types of fume. Three of the most common types of welding fume and their compositions are reported in the table below. Iron (Fe) is the majority or plurality of particles in each type of fume. All these types of fume contain Manganese (Mn), a known neurotoxicant.

Stainless steel welding contains nickel (Ni) and chromium (Cr) 6 (also known as chromium VI, or hexavalent chromium) compounds [10], both of which are known lung carcinogens. Some fume also contains chromium 3, which cannot enter cells easily and is less toxic.

Welding Fume Samples	Metal (weight %)*	Soluble/Insoluble Ratio
GMAW-mild steel	Fe 85 Mn 14	0.020
GMAW-stainless steel	Fe 57 Mn 13.8 Cr 20.2 Ni 8.8	0.006
Shielded MMAW-stainless steel	Fe 41 Mn 17 Cr 29 Ni 3	0.345 Soluble metals: Cr 87% Mn 11%

Table adapted from [1].

While it has been suggested that it is the Cr 6 and Ni compounds in fume that lead to elevated cancer risk, and thus that GMAW-mild steel welding fume poses little cancer risk, numerous studies have not made this association [1]. Instead, the IARC review determined that an elevated risk of lung cancer was present regardless of the welding processes or materials worked and consumed, a position also affirmed by other studies [36]. Most welders utilise different welding techniques in their work, making distinguishing them in studies difficult. Therefore, even though animal models show different lung responses to different welding techniques, such differences are not readily studied in human populations [1]. In the below, therefore, 'welding' should be taken as a broad category whose risks are similar across all techniques, except where a specific technique is identified in a study.

The risks of welding

Welding is associated with both acute and chronic health risks, the most well-studied of which is its link with lung cancer. In this section, the literature on both categories of risk is summarised. Some further risks, such as those from explosive welding gas, asphyxiation, or noise and vibration, are not covered here.

Acute

Acute irritant-induced asthma (formerly Reactive Airways Dysfunction Syndrome, RADS)

Reactive airways dysfunction syndrome (RADS) was the name of the syndrome, now called 'acute irritant-induced asthma', that consists of symptoms simulating asthma within 24 hours of a single, massive, chemical exposure [13]. These symptoms can persist for years, with a median symptom duration across all causative agents being 13 months [14]. It has been reported as a result of inhalation of welding fume [12].

Metal fume fever

Caused by the inhalation of Zinc Oxide, metal fume fever is a flu-like illness, often worse at the start of the working week, which presents with "fever, cough, sputing, wheezing, chest tightness, fatigue, chills, fever, myalgias, cough, dyspnea, leukocytosis with a left shift, thirst, metallic taste, and salivations" [35]. Symptoms resolve spontaneously.

Acute pneumonia

There is strong evidence that welders are at "increased risk of developing and dying from pneumococcal and unspecified lobar pneumonia." One study found that welders of working age were 3.58 times more likely to die of pneumococcal pneumonia than those in other occupations. It recommended vaccination against pneumococcal pneumonia and that HSE strengthen its recommendation for vaccination [38].

Chronic

Lung Cancer

The association between elevated lung cancer risk and welding is very well-established in the literature. The precise mechanistic link between welding and lung cancer has not been exhaustively described. Additional *in vivo* laboratory studies to further explore the linkage are needed [1]. However, many studies suggest that the presence of chromium 6, a known genotoxic carcinogen, and nickel in welding fume are the likely causes. In animal studies, it has been shown that fume "may act as lung tumour promoters, regardless of the presence or absence of potentially carcinogenic metals, such as chromium and nickel"[1]. Immunosuppression and chronic inflammation are other possible mechanisms [1].

Precise assessments of the elevation of the risk vary: a 16% increase in risk in a 2017 study on Canada [10] contrasts strongly with a 94% increase in risk for stainless steel welders found in a meta-analysis of five studies from 1994 in which both smoking and asbestos exposure were controlled for [11]. Other studies have also found a greater risk for stainless steel welders relative to other welders, although they were unable to quantify the exact increase in risk. Interestingly, this study also noted that overall mortality for stainless steel welders was lower than in the general population, a tendency they ascribed to the 'healthy worker effect' and stainless steel welding's relatively higher pay as well as its need for qualifications in some countries. However, the data from this study having been drawn from cohorts stretching back to 1950, this effect is perhaps no longer applicable [19].

More recent studies, using more recent data as well as more sophisticated methodologies, have largely replicated the results of the older studies. A 2013 pooled analysis of case-control studies found that even short-term (less than three years) welding work, whether regular or occasional, led to an increase in lung cancer risk of 14% and 13%, respectively. More than 25 years of welding was associated with 77% increase in lung cancer risk for welders and 40% for occasional welders. For those across the studies who had ever worked as welders, there was a 44% increase in overall lung cancer risk. Crucially, this assessment of risk was smoking-adjusted [15].

This is in keeping, as the authors of the above study note, with an earlier meta-analysis of 66 epidemiological studies conducted in 2006 which found an overall increase in lung cancer risk of 26% amongst welders, although without any noted difference between the three types of welding considered: shipyard, mild steel, and stainless steel welders. One important aspect of this study is that these results do not "support the hypothesis that stainless steel welders are at higher lung cancer risk than mild steel welders, despite their probable exposure to chromium and nickel compounds in welding fumes" [16]. The results of the 2013 study are also in keeping with a study conducted across the Nordic countries of occupational cancer risk which found a 33% increase in risk for lung cancer. This study did not adjust for smoking [17].

This should, however, not be taken to mean that the elevated risk of lung cancer among welders is due to the prevalence of smoking. Indeed, other studies that did adjust for smoking found higher risks for welders *after* controls for smoking had been put in place. In one study on Norwegian men using data from the period 1965-1980, the risk of lung cancer jumped from a 31% elevation to 48% after smoking was controlled for [18].

Other cancers

In addition to lung cancer, other cancers have been associated with welding. Multiple studies have found an elevated risk of kidney cancer, of approximately the same degree. In a Canadian study, a 30% increase in risk was reported [10] and the Nordic study reported a 25% increase in risk [17]. This same large-scale Nordic study found a 39% elevation in risk for renal pelvic cancer among welders [17]. The Canadian study found a 40% increase in the risk of bladder cancer [10]. Soft tissue cancers are rare, but in Norway, a doubling of risk was found for welders, the only occupation with a statistically significantly different risk in the country [17]. The Canadian study showed a 78% increase in the risk of mesothelioma, with extremely wide confidence intervals that reported up to a three-fold increase in risk [10]. In the study of the Nordic countries, welders found themselves in the highest category of risk amongst "seamen, mechanics, electrical workers, smelting workers, [...] and painters" [17].

In addition to fumes, arc welding generates intense UV radiation. This radiation can contribute to cancers of the eye. Some studies have found that welders face between a two and a ten-fold increase in the risk of developing ocular melanoma associated with eye burns (a proxy for UV

radiation from welding) [5 and 6, summarised in 4]. Other studies have found lower levels of increased risk, such as the large Nordic study which reported a 7% increase [17].

Cardiovascular problems

One longitudinal study found that over the course of 6 years, non-smoking welders' blood pressure increased to a statistically significant extent [29]. Similarly, found that years working as a welder were associated with higher blood pressure [30]. A further study found an elevated risk of acute myocardial infarction (12%), angina pectoris (11%) and chronic ischaemic heart disease (CHD) (17%) [31].

Neurological problems

'Parkinsonism' is an umbrella term to describe symptoms of muscle tremors, muscle rigidity, and slowness of movement. Its connections with welding are controversial and complex. It is known that manganese exposure can lead to manganism, a disease with similar symptoms to parkinsonism, but the literature on whether this translates to welding is inconclusive.

A 2007 review of the literature found that manganese exposure for welders was below that associated with clinical toxicity [27]. Another study suggested that "Epidemiologic studies have failed to show that welders are at increased risk for parkinsonism, but that does not rule out the possibility that an individual can develop manganism following intense exposure. However, those studies do indicate that such an occurrence would be rare." [33] However, it has been proposed that the model of very high levels of acute manganese exposure be replaced with a model of low-level chronic exposure to reflect the changing nature of exposure in industry [32, 39].

Although a 2005 study, despite recommending preventative measures, noted no consistent evidence of a dose-effect relationship between manganese exposure and parkinsonism [25], a 2016 study found that there was a strong correlation between "upper limb bradykinesia [impairment of voluntary motor control and slow movements or freezing], upper and lower limb rigidity, and impairment of speech and facial expression" and exposure to manganese [26]. Another study found a strong association between welding and parkinsonism in a cohort of 811

shipyard and fabrication welders: a 15.6% prevalence of parkinsonism in welders compared with 0% in the reference group [37].

Further, a literature review from 2009 found that welders were at risk of manganism and that this risk "increase[d] when the Mn content in the base metals and/or welding rods is high (e.g., railroad steel), when the electrode current densities are high (e.g., arc air cutting), when the arc time is high (actual welding vs. set up time), and when there is poor ventilation (e.g., enclosed spaces)" [28].

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