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Stainless Steel and Welding Fume

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Abstract

*Welding "**smoke**" is a mixture of very fine particles (**fumes**) and **gases.** Many of the substances in welding smoke, such as **chromium**, nickel, **arsenic,** asbestos, manganese, silica, beryllium, **cadmium,** nitrogen oxides, phosgene, acrolein, fluorine compounds, carbon monoxide, cobalt, copper, **lead,** ozone, selenium, and **zinc** can be extremely toxic.*
Welding fume is a mixture of airborne fine particles. Toxic gases may also be generated during welding and cutting.
*More than 90% of the fume arises from vaporisation of the consumable electrode, wire or rod as material is transferred across the arc or flame. The range of welding fume particle size is shown in relation to more familiar types of dust and fume. The respirable fraction of particles (especially less than **3µm**) are potentially more harmful as they can penetrate to the innermost parts of the lung.*
*Various **gases and fumes** can be generated during welding. Welding fumes are metal-containing aerosols consisting of particles formed through complex vaporisation-condensation-(oxidation) or vaporisation-(oxidation)-condensation processes during welding. The fumes are therefore complex in their composition and their structure.*

Key words:. *Hexavalent chromium, crom, nichel, mangan, silica, beriliu, cadmiu, oxizi, compuşi de fluor, cobalt, cupru, plumb, selenium, zinc, respirable fraction of particles, toxic gases may.*

Introduction

Welding fumes are a complex mixture of gases and small particulates of metal oxides formed by the vaporization and oxidation of metal during the welding process (Lockey et al., 1988; Yu et al., 2000). The nature of respirable fumes depends upon the type of welding and the composition of electrode, filler wire, and fluxes (Antonini et al., 1996; Lockey et al., 1988; Sferlazza and Beckett, 1991; Yu et al., 2000).

A sample of suspended particulate matter in the indoor air of a **steel welding** workshop located in an industrial area of Raipur was collected and analysed for toxic metals (**Cu, Co, Cr, Cd, Fe, Pb, Mn, Ni, Zn and Hg).** A sample of the welding electrodes was also analysed. The occurrences of the **heavy metals** in the suspended particulate matter were found in the order: Fe > Mn > **Cr** > Zn > Ni > **Pb** > Cu > Co > **Hg > Cd**. The same order was found in the electrode material, which suggested the transfer of toxic metals from the welding electrodes to the particulate matter generated in the workplace during the arc welding process.

Welding Gases and Fumes

Fume

The composition of the welding fumes and their generation rate will depend largely on the welding process employed and the filler material used (if any), which is the major source of fumes and which has an influence on metal speciation in the fumes.
The rate of generation of fumes during arc welding of stainless steel depends on various factors:
-welding current (current density)
-arc voltage (arc length)
-type of metal transfer (type of filler material and/or welding process)
-shielding gas or welding atmosphere

Gases

Gases encountered in welding may be:
- Fuel gases which, on combustion, form carbon dioxide and, if the flame is reducing, carbon monoxide
- Shielding gases such as argon, helium and carbon dioxide, either alone or in mixtures with oxygen or hydrogen
- Carbon dioxide and monoxide produced by the action of heat on the welding flux or slag
- Nitric oxide, nitrogen dioxide and ozone produced by the action of heat or ultraviolet radiation on the atmosphere surrounding the welding arc
- Gases from the degradation of solvent vapours or surface contaminants on the metal.

The degree of risk to the welder's health from fume/gases will depend on:
-composition
-concentration
-the length of time the welder is exposed

Generally, welding fumes and gases come from:
- the base material being welded or the filler material that is used;
- coatings and paints on the metal being welded, or coatings covering the electrode;
- shielding gases supplied from cylinders;
- chemical reactions which result by the action of ultraviolet light from the arc, and heat;
- process and consumables used;
- contaminants in the air, for example vapours from cleaners and degreasers.

Materials Used in Welding

Core and filler metals

Core and filler metals are usually made of alloy similar in chemical composition to the materials being welded. The most commonly used material is mild steel. Special steels may contain chromium, nickel, molybdenum, aluminium, cobalt, vanadium or tungsten. **Stainless steel electrodes may contain up to 26 per cent chromium and** 21 per cent **nickel.** Manganese as high as 14 per cent may also be present in certain types of steel electrodes, for example, high-manganese hard facing electrodes. High-chromium hard facing electrodes may contain up to 30 per cent chromium, present as chromium metal and chromium carbides.

Composition/information on Ingredients
General Information

Welding rods, and similar products, as supplied, are considered to be alloys in massive form and so do not require labelling according to **EU Directive 1999/45/EC.**

Table 1. Hazardous component(s)

Ingredient	EC Number CAS Number Index Number	Symbols	Risk Phrases *	Concentration (weight %)
Manganese (Mn)	231-105-1 7439-96-5	Xn, N, F	R11-20-50/53	<1 %
Chromium (Cr)	231-157-5 7440-47-3	-	R53	3-8 %
Nickel (Ni)	231-111-4 7440-02-0 028-002-00-7	Xn	R40-43	<0.5 %
Molybdenum (Mo)	231-107-2 7439-98-7	F, N	R11-50	1-2.5 %
Cobolt (Co)	231-158-0 7440-48-4 027-001-00-9	Xn	R42/43-53	<0.5 %
Vanadium (V)	231-171-1 7440-62-2	Xi, N	R36/37/38-50	<1 %
Copper (Cu)	231-159-6 7440-50-8	Xn, N	R20-50-53	<0.5 %
Iron (Fe)	231-096-4 7439-89-6	O	R7	>75 %

Table 2. Substances found in welding fume

Substance	**8hr TWA**	**15 min STEL**
Beryllium & beryllium compounds (as Be)	0.002 mg/m ^{3}	
Cadmium oxide fume (as Cd)	0.025 mg/m ^{3}	
Chromium VI compounds (as Cr)	0.05 mg/m ^{3}	
Cobalt & cobalt compounds (as Co)	0.1 mg/m ^{3}	
Nickel (insoluble compounds)	0.5 mg/m ^{3}	
Fluoride (as F)	2.5 mg/m ^{3}	
Iron oxide, fume (as Fe)	5 mg/m ^{3}	10 mg/m ^{3}
Manganese, and its inorganic compounds	0.5 mg/m ^{3}	
Ozone		0.2 ppm
Nitric Oxide	1 ppm	
Nitrogen dioxide	1 ppm	

Chromium III compounds (as Cr)	0.5 mg/m^3	
Barium compounds, soluble (as Ba)	0.5 mg/m^3	
Carbon monoxide	30 ppm	200 ppm
Copper fume	0.2 mg/m^3	

Welding Fume Formation

In the electric arc, the temperature is very high (of the order of 6,000 - 8,000° C for the GTAW, GMAW, FCAW and SAW processes, and up to 10,000 - 20,000° C for the PAW process) and well above the boiling point of the base and filler materials (2,680°C for Cr, 2,860°C for Fe and 2,915°C for Ni).

With the exception (in most cases) of GTAW and PAW processes, the melted metal is transferred in the form of droplets from the filler material (GMAW, FCAW, SMAW and SAW processes) to the molten pool or weld pool. A small fraction of the filler metal is vaporised-condensed (oxidised) or vaporised (oxidised)-condensed, creating small particles with an individual diameter ranging from 0.05 to 0.2 μm.

Fume particles formed during welding, whatever the filler metal, can be split into three categories:
-Spherical particles which are agglomerated in the form of clusters with a linear size of the order of **4 μm** and a maximum of **10 μm.**
-Particles which are agglomerated in the form of chains with a linear size of the order of **4 μm** and a maximum of **10 μm.**
-Spherical particles which are agglomerated in the form of globules (spherical agglomerates) with a diameter up to **100 μm.**
This typical situation is summarised in Table 2.

STEL - Short-term exposure limit
8-hr time-weighted averages **(TWAs)**
American Conference on General and Industrial Hygiene **(ACGIH)**

THRESHOLD LIMIT VALUE: The ACGIH recommended limit for welding fume is 5 mg/m3.

EFFECTS OF OVEREXPOSURE: short-term Overexposure (acute) to welding fumes my result in such discomfort as: dryness or irritation of the nose, throat, or eyes, dizziness or nausea. Long-term Overexposure (chronic) may lead to siderosis and affect pulmonary function. Arc rays can injure eyes and burn skin. Electric shock can kill. Noise can damage hearing.
CARCINOGENIC: Chromium and Nickel and their compounds are listed by the IARC and the NTP as posing a carcinogenic risk to humans.

Generally, welding fumes and gases come from:
- the base material being welded or the filler material that is used;
- coatings and paints on the metal being welded, or coatings covering the electrode;
- shielding gases supplied from cylinders;
- chemical reactions which result by the action of ultraviolet light from the arc, and heat;
- process and consumables used;
- contaminants in the air, for example vapors from cleaners and degreasers.

The health effects of welding exposures are difficult to list, because the fumes may contain so many different substances that are known to be harmful (depending on the factors listed above).

The individual components of welding smoke can affect just about any part of the body, including the lungs, heart, kidneys, and central nervous system.

Welders who smoke may be at greater risk of health impairment than welders who do not smoke, although all welders are at risk.

Exposure to welding smoke may have short-term and long-term health effects. These effects are described below:

Table 3. OSHA PEL for some components of Stainless Steel Weld Fume

Fume Component	Current PEL (mg/m^3) PEL Permissible Exposure Limit	Anticipated PEL (mg/m^3) PEL Permissible Exposure Limit
Cr^{6+}, chromium chromates	100	100
Mn, metal and insoluble compounds	5000	1000
Ni, metal and insoluble compounds	1000	100

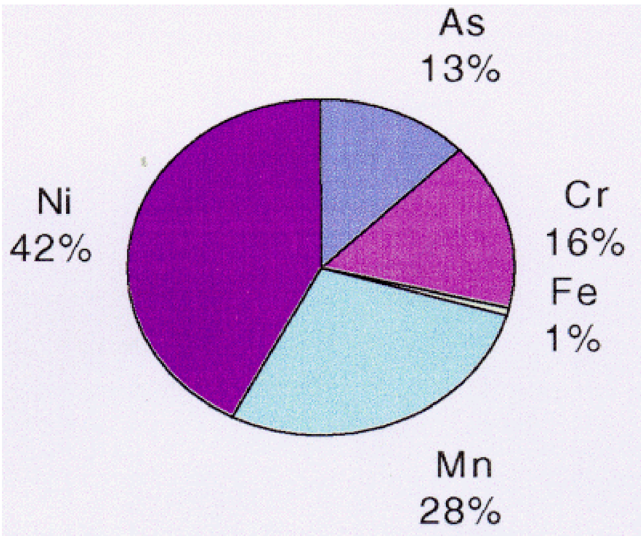

Fig. 1. Five Elements Account for 100% of the Overexposures

Toxicity refers to the capacity of an agent to produce disease or injury. The evaluation of toxicity takes into account the route of exposure and the actual concentration of an agent in the body.

Lead

Potential lead exposure occurs during welding and cutting of any metal coated with lead or lead based paint. Lead poisoning is rare in welders, but may occur in persons employed in operations such as cutting lead-painted steel in ship breaking and bridge demolition. Occupational lead poisoning, which in welders results from exposure to lead oxide fume, may affect the blood, gastro intestinal tract and nervous system.

Cadmium

Cadmium may be present as a coating in certain materials being welded. Cadmium oxide fume on inhalation may cause acute irritation of the respiratory passages, bronchitis, chemical pneumonia or excessive fluid in the lung tissues (pulmonary oedema). There may be a latent period of several hours between exposure and onset of symptoms. The effects of overexposure to cadmium fumes may resemble metal fume fever initially. A single exposure to a very high concentration of cadmium oxide fume may be fatal. Chronic cadmium poisoning results in injury to lungs and kidneys.

Chromium

Chromium may be present as a coating on the work piece, and mainly in stainless steel, hard facing and chrome-alloy electrodes. Chromium is normally not present in any significant amount in aluminium alloys. Chromate, which may be generated in stainless steel welding fumes or in fumes from hard facing and chrome-alloy electrodes, is an irritant to the mucosal tissue in the respiratory tract. Exposure to fume containing high concentrations of water-soluble chromium (VI) during the welding of stainless steel in confined spaces has been reported to result in both acute and chronic chrome intoxication, dermatitis and asthma.

Epidemiological studies and animal tests have confirmed certain chromium (VI) compounds as occupational carcinogens. These health risks were determined from non-welding occupations.

GMAW stainless steel welders are usually likely to be exposed to much smaller concentrations of chromium (VI) than MMAW stainless steel welders. A considerable amount of stainless steel welding is carried out nowadays using GMAW and GTAW methods.

Chromium (III) compounds are generally believed to be biologically inert. Welding fumes may contain Cr2O3 (a chromium (III) compound), or double oxides, such as FeO Cr2O3, or both.

Chromium as a pure metal has no reported human or environmental toxicity effects. Both acute and chronic toxicity of chromium are mainly caused by **hexavalent chromium compounds (Cr VI).**

Conclusions

Welding fumes present a hazard, not the ingredients of the electrode.

Welding fumes and gases **CANNOT** be classified simply. The composition and quantity of these are dependent upon the metal being welded, procedures, electrode type and electrode size. Other conditions which also influence the composition and quantity of the fumes and gases to which the workers may be exposed include: coatings on the metal being welded (such as paint, plating or galvanising), the number of welders and the volume of the work area, the quality and amount of ventilation, the position of the welder's head with respect to the **fume plume**, as well as the presence of contaminants in the atmosphere.

From the control point of view, investigation of fume formation mechanisms in different

welding methods, particularly the generation of hexavalent chromium (Cr(VI)), is continuously of great interest (Dennis *et al*., 1996, 1997; Hewitt and Madden, 1989). In addition to process modification, control at the source is an effective way to eliminate or reduce welding fumes and grinding dust (BOHS,1987; HSE, 1990). However, in many cases, source controls, such as local exhaust ventilation, are difficult to implement and use or they capture only part of the contaminants generated. Therefore, general

ventilation airflows play an important role in the contaminant removal process, particularly in large industrial halls.

Welding fumes and gases **CANNOT** be classified simply.

Baum and Mulholland (1979) have published a theory for particle coagulation in buoyant plumes. They used the theory for plumes from smokestacks and from small smoldering sources. Mulholland and Ohlemiller (1982) have also used this theory for smoldering sources. Here, the use of the Baum—Mulholland theory is enlarged and applied to welding fume buoyant plumes. **SINCE WELDING IS A VERY COMPLICATED AND NOT YET FULLY UNDERSTOOD PROCESS,** it is not possible to measure or calculate all necessary initial parameters for the theory.

Welding produces a variety of toxic fumes, depending on the metals being fused or cut and the rods used to make the bonds. For instance, hexavalent chromium is a toxic associated with the welding of stainless steel.

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Oțelurile aliate şi vaporii de sudare

Rezumat

"Fumul " de sudare este un amestec de particule foarte fine (vapori/aburi) şi gaze. Majoritatea substanțelor din fumul de sudare, precum CROM, nichel, azbest, mangan, silica, beriliu, CADMIU, oxizi de azot, fosgen, acroleina, compuşi de fluor, monoxid de carbon, COBALT, CUPRU, PLUMB, ozon, selenium şi ZINC pot fi extreme de toxici.
Vaporii de sudare sunt un amestec de particule fine în suspensie. Gazele toxice pot fi generate de asemenea în timpul sudpării şi tăierii.
Mai mult de 90% din vapori apar din vaporizarea electrozişlor consumabili, sârmă sau tijă întrucât materialul este transferat de-a lungul arcului sau flăcării. Domeniul de mărime a particulelor de vapori de sudare este arătat in raport cu mai multe tipuri de praf şi vapori. Fracția respirabilă a particulelor (în special mai mici decât 3µm) sunt potențial mai dăunătoare deoarece ele pătrund în cele mai adănci părți ale plămânului.
Diverse gaze şi vapori pot fi generate în timpul sudării. Aburii de sudare sunt aerosoli – particule fine dispersate ca un atomizer de particule fine, conținând metale constând în particule formate printr-un process complex de condensare-vaporizare (oxidare) sau vaporizare -(oxidare)- condensare în timpul sudării. Aburii sunt prin urmare complexi în compoziția şi structura lor.