Workplace Exposure Standard (WES) review

WELDING FUME
(NOT OTHERWISE CLASSIFIED)
(CAS NO: N/A)

September 2021

Te Kāwanatanga o Aotearoa
New Zealand Government

WORKSAFE
Mahi Haumaru Aotearoa

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Terms that are **bold** (first occurrence only) are further defined in the Glossary.

Summary

	CURRENT	PROPOSED
WES-TWA	5 **mg/m³**	Removal of WES-TWA
WES-STEL	–	–
WES-Ceiling	–	–
Notations	Confirmed carcinogen	Confirmed carcinogen

TABLE 1: Current and proposed Workplace Exposure Standard (**WES**)

Recommendation and basis for WES

It is proposed that WorkSafe:

- remove the WES-TWA for welding fume of 5 mg/m³.

Based on the classification of welding fume as a known human carcinogen by **IARC**, and lack of data linking total welding fume levels to health effects. Exposure assessment of welding fume should be based on measurement of known or expected components in welding fume.

Discussion

> "Welding fumes are produced when metals are heated above their melting point, vapourize and condense into fumes. The fumes consist of predominantly fine solid particles with an aerodynamic diameter of less than 1 **µm**, and are a complex mixture of particles from the wire or electrode, base metal, or any coatings on the base metal. They consist mainly of metal oxides, silicates, and fluorides. Exposure to various gases also occurs during welding, such as nitrogen oxides (NOx), carbon monoxide (CO), or ozone (O_3). Welding fumes and welding gases are distinct in that fumes contain solid particles that are temporarily suspended in the air due to a solid material being heated (such as metals), whereas gases are molecules in a gaseous state in the ambient air that have been generated by or are used as part of the welding process (for example, the shielding gas)". (ISO 2009 as cited in IARC 2018).

For the purposes of this review, welding is taken as being any process with the potential to create a metal fume and includes thermal processes used to:

i. fuse metals at high temperatures, as distinct from lower temperature metal-joining techniques such as brazing and soldering, which do not melt the base metals
ii. cut metals, and
iii. purify or smelt metals.

The review focuses on the evidence of health effects of welding fume, as a whole (total fume). Out of scope is evidence for the health effects of individual components of welding fume, for which, there are workplace exposure standards, for example, chromium (VI), nickel, manganese, etc. These substances have been previously addressed in the WES review for welding fume in 2018.

Carcinogenic and genotoxic risks

The International Agency for Research on Cancer (IARC) evaluation of welding fume concluded that:

> ”There is sufficient evidence in humans for the carcinogenicity of welding fumes. Welding fumes cause cancer of the lung. Positive associations have been observed with cancer of the kidney.
>
> “There is limited evidence in experimental animals for the carcinogenicity of gas metal arc stainless steel welding fumes.” (IARC 2018).

With an overall evaluation that:

> “Welding fumes are *carcinogenic to humans* (Group 1).” (IARC 2018).

The rationale being:

- More than 20 available case-control studies, more than 20 available cohort studies, and 6 population-based cohort studies reported elevated risks of lung cancer for workers employed as welders reporting welding as their job task, or classified as or reporting to be exposed to welding fumes.
- Chance, information bias, selection bias, tobacco smoking, and occupational exposure to asbestos were unlikely to explain all of the observed excess risk of lung cancer among welders.
- “…the observed patterns of risk estimates by cumulative exposure and by duration add support to the association between exposure to welding fumes and increased risk of cancer of the lung.” (IARC 2018).

Honaryar *et al*. (2019) conducted a meta-analysis in parallel to the IARC Monograph 118 re-evaluation of the carcinogenicity of welding fumes. The risk of lung cancer in welders being exposed to welding fumes were:

- overall, a meta-relative risk [**mRR**] 1.43 (**95% CI** 1.31-1.55)
- studies that adjusted for smoking and asbestos exposure simultaneously (mRR 1.17; 95% CI 1.04-1.38)
- mild steel welders (mRR 1.44; 95% CI 1.07-1.95)
- stainless steel welders (mRR 1.38; 95% CI 0.89-2.13)
- exclusively gas welding (mRR 1.71; 95% CI 1.10-2.66)
- exclusively arc welding (mRR 1.36; 95% CI 0.70-2.66)
- duration as a welder showed statistically significant associations with cancer risk: p = 0.001 using a non-linear (spline) model, and **p** = 0.009 using non-parametric model.

Information could not be found on the justification for the selection of each country’s limit value for welding fumes. With the exception of Austria, the limit values were for the inhalable fraction of dust.

> “Limit values for occupational exposure to welding fumes are generally set at 5 mg/m^3; exceptions are in the People’s Republic of China (limit value of 4 mg/m^3) and the Netherlands where, on 1 April 2010, a limit value of 1 mg/m^3 over 8 hours came into force.” (IARC 2018).

For countries that do have a limit value for welding fume, it is assumed it is set for the inhalable fraction (except for Austria) (IFA 2020). However, welding fumes "consist of predominantly fine solid particles with an aerodynamic diameter of less than 1μm, and are a complex mixture of particles from the wire or electrode, base metal, or any coatings on the base metal." (IARC 2018). This suggests that limit values set for the inhalable fraction for welding fume may not be appropriate, given that "welding fume consists of airborne particles generated by welding and allied processes. In general, these particles are less than 1μm in diameter, and respirable" (Standards Australia 2006).

> "Some countries no longer have an exposure limit for welding fumes, but instead use limits for specific metals in welding fumes or respirable dust (for example, Germany, the United Kingdom, and the USA) (BG-Regel, 2006; OSHA, 2013; HSE, 2017). In the United Kingdom a generic exposure limit to welding fumes of 5 mg/m^3 as total inhalable particulate (TIP) was withdrawn in 2005 (Garrod & Ball, 2005), as the limit was not considered to be protective of health." (IARC 2018).

In recent years, WorkSafe has lowered the WES for some metals that may be present in welding fume to protect against various adverse health effects. Mild steel and stainless steel are common alloys involved in welding, which contain mostly iron, with smaller amounts of manganese, chromium, nickel and other additive metals. The current WES of 5 mg/m^3 for welding fume would not be adequate as an indicator for potential exposure levels of various metals, when the WES-TWA for metals involved in welding (other than aluminium, iron, tungsten, and tin) are lower than 0.5 mg/m^3 (Table 2). Furthermore, some metals have a WES for the respirable fraction – this is inconsistent with the current welding fume WES, which measures the inhalable fraction.

SUBSTANCE	INHALABLE FRACTION WES-TWA (mg/m^3)	RESPIRABLE FRACTION WES-TWA (mg/m^3)
Aluminium, as Al Welding fumes	5	
Antimony and compounds, as Sb	0.5	
Arsenic and soluble compounds, as As	0.05	
Beryllium and compounds, as Be	0.0002	
Cadmium and compounds, as Cd	0.01	0.002
Chromium (VI) compounds, as Cr	0.01	
Cobalt metal dust and fume, as Co	0.02	
Copper fume, as Cu	0.2	
Iron oxide dust and fume, as Fe	5	
Lead, inorganic dusts and fumes, as Pb	0.05	
Manganese fume, dust and compounds, as Mn	0.2	0.02
Molybdenum, as Mo Soluble compounds Insoluble compounds	 5 10	

SUBSTANCE	INHALABLE FRACTION WES-TWA (mg/m^3)	RESPIRABLE FRACTION WES-TWA (mg/m^3)
Nickel Elemental or metallic Inorganic compounds	 0.02	 0.005 0.005
Selenium and compounds, as Se	0.1	
Tin metal, oxide and inorganic compounds except SnH_4, as Sn	2	
Titanium dioxide	10	
Tungsten, as W Insoluble compounds	 5	
Vanadium, as V_2O_5 Respirable dust and fume		 0.05
Zinc oxide fume		3

TABLE 2:
Current WorkSafe WES for metals that may be present in welding fume

Conclusions

Based on the documentation discussed above, and informed by the conclusions of the IARC monograph, WorkSafe considers its current WES-TWA for welding fume of 5 mg/m^3, to be inappropriate to manage health risks from possible workplace exposure.

It is recommended that the WES-TWA for welding fume of 5 mg/m^3 be removed, based on the heterogeneous nature of welding fumes, the carcinogenic classification of many of its components, and its classification as a known carcinogen by IARC. Exposure assessment of welding fume should therefore be based on a risk assessment of known or expected components in welding fume, which would include metal fume as well as shielding gases and contaminants produced during combustion of surface coatings and cleaning products, where present.

Appendix 1: Glossary

TERM	MEANING
95% CI or $CI_{95\%}$	95% Confidence Interval.
IARC	The International Agency for Research on Cancer – an agency of the World Health Organisation.
mg/m^3	Milligrams of substance per cubic metre of air.
mRR	Meta-relative risk
µm	Micrometre or one millionth of a metre.
p or *p*	Calculated probability value.
WES	Workplace Exposure Standard – WESs are values that refer to the airborne concentration of substances, at which it is believed that nearly all workers can be repeatedly exposed to, day after day, without coming to harm. The values are normally calculated on work schedules of five shifts of eight hours duration over a 40 hour week. A WorkSafe term.
WES-Ceiling	A concentration that should not be exceeded at any time during any part of the working day.
WES-STEL	The 15-minute time-weighted average exposure standard. Applies to any 15-minute period in the working day and is designed to protect the worker against adverse effects of irritation, chronic or irreversible tissue change, or narcosis that may increase the likelihood of accidents. The WES-STEL is not an alternative to the WES-TWA; both the short-term and time-weighted average exposures apply. Exposures at concentrations between the WES-TWA and the WES-STEL should be less than 15 minutes, should occur no more than four times per day, and there should be at least 60 minutes between successive exposures in this range. A WorkSafe term.
WES-TWA	The average airborne concentration of a substance calculated over an eight-hour working day. A WorkSafe term.

Appendix 3: References

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