## IARC Monograph Volume 118: Welding, Molybdenum Trioxide, and Indium Tin Oxide Neela Guha for the IARC Monographs Programme (IMO Group / ESC Section - International Agency for Research on Cancer) **EXPOSURE DATA: WELDING** WELDING AND LUNG CANCER SUMMARY OF EVALUATIONS

Table 1. Summary of eva	luations from IARC Mon	ograph Volume 118, by a	agent and subgroup <sup>(1)(2)(3)</sup>	
Evaluations	Welding fumes	UV radiation from	Molybdenum trioxide	Indium tin oxide
		welding		
	Sufficient (lung);	Sufficient (ocular		
Humans (cancer)	Limited (kidney)	melanoma)	No data	No data
	Limited (gas metal			
	arc-stainless steel			
Animals (evaluation)	welding fumes)	No data	Sufficient	Sufficient
Mechanisms (key	Strong (chronic			
characteristics)	inflammation,			
	immunosuppression)	No data	Weak	Strong (chronic inflammation)
Overall evaluation	1	1	2B	2B
Previous evaluation	2B in 1999*	none	none	none
Occurrence/Notes	*2B evaluation based	'UV radiation' was	High-production volume;	Low-production volume;
	on 'limited evidence'	classified as Group 1	mostly used in steel	mostly used for producing
	in humans and	in 2009	production; exposure	conductive films on panels
	'inadequate		occurs in occupational	used in electronic devices;
	evidence' in		settings (eg, welding) but	exposure mainly from ITO
	experimental animals		rare from environment	production and processing
Overall evaluations: Gro	up 1 Carcinogenic to hu	mans: Group 2B Possible	v carcinogenic to humans	

Overall evaluations: Group 1, Carcinogenic to humans; Group 2B, Possibly carcinogenic to humans

## BACKGROUND: Welding

- Welding is the process of joining metals through coalescence
- > Predominant techniques: gas (fuel gases used to generate heat), arc (electricity used to generate arc) Predominant metals welded: mild steel, stainless steel (SS, contains chromium and nickel compounds)
- which are Group 1 carcinogens)
- Tobacco smoking and asbestos are potential confounders for assessing lung cancer Welders may smoke more than the general population
  - Asbestos exposure: work in shipyards, electrodes, heat protective equipment worn by welders
- Welders are co-exposed to several substances already evaluated by IARC (Table 2)

Agent	Evidence for Carcinogenicity		Overall	Most recent	Occurrence	Welding types***
	Humans	Animals	Evaluation	Volume (Year)		
Arsenic and inorganic arsenic compounds	Sufficient	Sufficient	1	100C (2012)	Impurity in some mild stainless welding fumes	All
Asbestos	Sufficient	Sufficient	1	100C (2012)	Insulation material and in heat-protective equipment of welders and the weld	Shipyard welding
Beryllium and beryllium compounds	Sufficient	Sufficient	1	100C (2012)	Hardening agent in copper, magnesium, aluminum alloys and electrical contacts	GMAW, GTAW
Cadmium and cadmium compounds	Sufficient	Sufficient	1	100C (2012)	Platings on base metals, SS containing cadmium	All
Chromium VI compounds	Sufficient	Sufficient	1	100C (2012)	Alloy in stainless steel, also in welding rods	All SS
Electric fields, extremely low-frequency	Inadequate	Inadequate	3	80 (2002)	Electrical currents from welding processes	All—more with processe resistance welding)
Formaldehyde	Sufficient	Sufficient	1	100F (2012)	Metal coatings, degreasing solvents	All
Inorganic Lead compounds	Limited	Sufficient	2A	87 (2006)	In solder, brass and bronze alloys, Welding on lead containing or coated materials	GMAW, GTAW
Magnetic fields, extremely low-frequency	Limited	Inadequate	2B	80 (2002)	Electrical currents from welding processes	All—more with processe resistance welding)
Nickel Compounds	Sufficient	Sufficient	1	100C (2012)	Alloy in stainless steel, also in welding rods	All SS
Silica dust, crystalline, in the form of quartz or cristobalite	Sufficient	Sufficient	1	100C (2012)	Some welding fluxes contain silica	GMAW, FCAW, GTAW
Titanium dioxide	Inadequate	Sufficient	2B	93 (2010)	Found in SMAW (MMA) electrodes	SMAW (MMA)
Ultraviolet Radiation**	Sufficient	Sufficient	1	100D (2012)	Arcs from welding guns	All
Iron Oxides* (Iron and steel founding)	Sufficient	Inadequate	1	100F (2012)	Main component of steel	All
Vanadium pentoxide	Inadequate	Sufficient	2B	86 (2006)	Alloy in stainless steel	All SS
Outdoor Air Pollution (PM 2.5)	Sufficient	Sufficient	1	109 (2016)	PM <sub>2.5</sub> generated from all welding processes	All
Welding Fumes	Limited	Inadequate	2B	49 (1990)	Generated from welding processes	All

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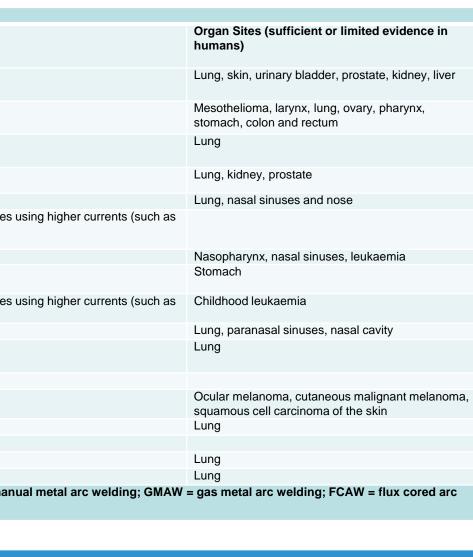
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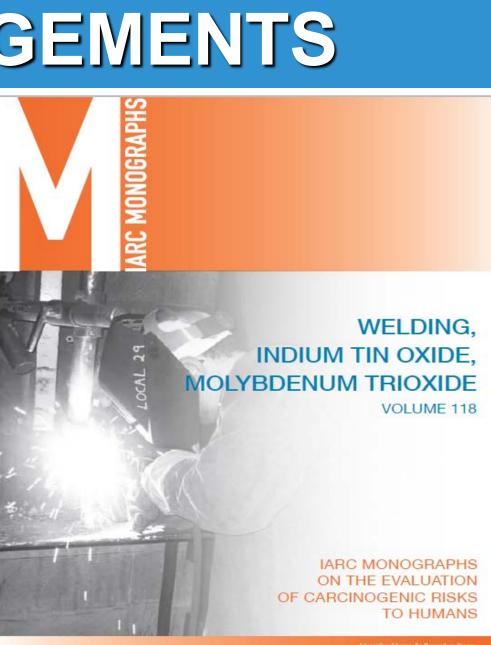
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> The IARC Working Group (WG) estimated 11 million persons work as welders worldwide and ~ 110 million workers incur welding related exposures (in jobs that routinely or intermittently weld) (Table 3)

Welders were estimated to represent 0.31% of the economically active population using census microdata gathered from 60 countries from ILO 2010 estimate of economically active population worldwide (3.5 billion) was applied

	-	f welders worldwide based on publically available population data, sorted by the number of v		Dorocat
Country	Census year	Occupational designation	Number	Percent welder**
hina	1990	Welders	1 798 300	0.27%
Inited States	2010	Welding, soldering, and brazing workers	727 122	0.40%
ndia	2004	Welders and flame cutters	499 219	0.14%
iet Nam	2009	Metal moulders, welders, sheet-metal workers, structural metal prepares, and related workers	339 106	0.71%
Brasil	2010	Welders and flame cutters	292 365	0.34%
pain	2001	Welders, laminators, metal structure assemblers, blacksmiths, toolmakers, and similar	262 620	1.61%
Inited Kingdom	2001	Metal forming; welding and related trades	227 044	0.55%
lexico	2010	Welders and flame cutters	191 819	0.45%
ligeria	2010	Welders and flame-cutters	190 637	0.27%
hilippines	2000	Metal moulders, welders, and sheet-metal workers	185 060	0.32%
slamic Republic of an`	2006	Welders and flame cutters	150 439	0.87%
ndonesia	2005	Welders and flame cutters	142 572	0.16%
South Africa	2007	Metal moulders, welders, sheet-metal workers, structural-metal preparers, and related trades workers	121 635	0.99%
Germany (West)	1987	Welder	110 040	0.39%
Canada	2006	Welder	103 000	0.61%
gypt	2006	Metal moulders, welders, sheet-metal workers, structural- metal preparers, and related trades workers	99 070	0.49%
hailand	2000	Metal moulders, welders, sheet-metal workers, structural- metal preparers, and related trades	97 626	0.20%
		workers		
Australia**	2011	Structural steel and welding trades workers	86 400	0.77%
Norroco Pomania	2004	Moulders, welders, and sheet metal workers Wolders and flame outtors	85 320	0.91%
lomania Portugal	2002 2011	Welders and flame cutters sheet and structural metal workers, moulders and welders, and related workers	80 460 76 580	0.95% 1.55%
letherlands*	1996	Welders	75 000	1.21%
/enezuela	2001	Mold-press workers, welders, laminators, boilermakers, assemblers of metal structures, and similar	70 170	0.31%
<b>l</b> alaysia	2000	Metal moulders, welders, sheet metal workers, structural metal preparers and related trades workers	43 400	0.53%
Cuba	2002	Molders, welders, panel beaters, assemblers	39 710	0.92%
Ecuador	2010	Sheet and structural metal workers, moulders, and welders, and related workers	37 640	0.64%
Peru	2007	Plumbers and pipe fitters, welders and flame cutters, sheet metal workers, and structural-metal preparers and erectors	37 350	0.36%
rance	2011	Skilled metal welders	36 164	0.14%
Senegal	2002	Metal moulders, welders, sheet-metal workers, structural- metal preparers, and related trades	25 550	0.80%
Bolivia	2001	workers Moldor woldors, lominators, bailarmakars, assemblars of motal structures, and similar	22.000	0.27%
Panama	2001	Molder, welders, laminators, boilermakers, assemblers of metal structures, and similar Moulders, welders, boilermakers, fitters of metallic structures and related	22 090 21 550	1.53%
ameroon	2010	Sheet and structural metal workers, moulders and welders and related workers	19 940	0.40%
El Salvador	2003	Metal moulders, welders, sheet-metal workers, structural- metal preparers, and related trades workers	17 930	0.91%
Guinea	1996	Metal moulders, welders, sheet-metal workers, structural-metal preparers, and related trades	17 070	0.50%
Kenya	1989	workers Welder	15 680	0.21%
		Metal moulders, welders, sheet-metal workers, structural-metal preparers, and related trades		
lozambique	2007	workers	14 490	0.18%
<b>N</b> alawi	2008	Plumbers, welders, sheet metal and structural metal preparers and erectors	14 240	0.34%
Costa Rica	2000	Molders, welders, locksmiths, boilermakers, metal structure builders and similar	13 810	1.06%
<b>N</b> ali	2009	Welder	12 860	0.23%
ambia	2010	Metal moulders, welders, sheet metal workers, structural metal preparers, and related trades	12 620	0.32%
		workers Welders and flame cutters		
Pakistan	1973	Welders and flame cutters Metal moulders, welders, sheet-metal workers, structural- metal preparers, and related trades	12 353	0.07%
licaragua	2005	workers	12 040	0.69%
Greece	2001	Welders and flame cutters	11 330	0.27%
lamaica	2001	Metal moulders, welders, sheet-metal workers, structural-metal preparers, and related trades	11 263	1.17%
		workers		
reland	2006	Welders and steel erectors	10 090	0.41%
Ethiopia	1994	Welders, metal moulders, and related trades workers Metal moulders, welders, sheet-metal workers, structural- metal preparers, and related trades	9,297	0.04%
laiti	2003	workers Metal moulders, welders, sheet-metal workers, structural-metal preparers, and related trades	7,990	0.38%
Jruguay	2006	workers	7,553	0.58%
Jganda	2002	Welders, sheet metal workers, metal moulders	7,380	0.10%
Kyrgyz Republic	1999	Welders and flame cutters	7,220	0.42%
Cambodia	2008	Sheet and structural metal workers, moulders and welders, and related workers Welding, Seldering, and Brazing Workers	6,650	0.10%
Puerto Rico Armenia	2010 2011	Welding, Soldering, and Brazing Workers Sheet and structural metal workers, moulders and welders and related workers	5,220 4,930	0.33% 0.45%
rmenia	1997	Welders and flame cutters	4,930 4,320	0.45%
ay iji	2007	Metal workers	3,240	1.34%
witzerland	2000	Welders and flame cutters	2,670	0.07%
Rwanda	2002	Workers for metal smelting, foundry, welding, metal sheet work, boiler making, metal frame for	2,390	0.07%
	2002	houses and buildings, and assimilated Metal moulders, welders, sheet-metal workers, structural-metal preparers, and related trades	1,810	0.23%
londolla	_000	workers	.,010	5.2070
	1000	Ovurfuel outtore: weldere, coldering by hand or machine, cleatric weldere, and blow to the weld'	1 400	0 1 5 0 /
Mongolia Paraguay	1982	Oxyfuel cutters; welders, soldering by hand or machine, electric welders, and blowtorch welding Metal moulders, welders, sheet-metal workers, structural-metal preparers, and related trades	1,460	0.15%

Exposure assessment methods of epidemiologic studies were reviewed systematically to inform the evaluation (Table 4)

Table 4. Detailed review of exposure assessment methods of epidemiologic studies Exposure assessmen method

> Prospective cohort study, men and women aged 55-69 years in September 1986. Job history was obtained via selfadministered questionnaire, collecting data on job title, company and department, and period

**Exposure to welding fumes** assessed specifically. Blinded exposure assessment. Any exposure misclassification therefore likely to be non-differential. All available information used (job title, type and name of the company, what was being produces in the department, time period).



Photo courtesy of Dr. David Christiani





World Health Organization

Bouvard





assessment

Elisabeth







Elbers

El Ghissassi

Grosse

van Loon No quantitative data on al. (1997 welding fumes. ob histories only up to start of follow-up, so may have missed up to 10 years of the end of

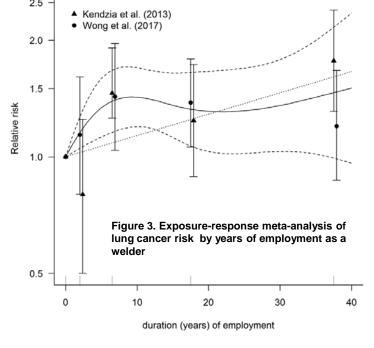
Probability of exposure to welding fumes (particularly stainless steel welding), classified into four categories (no exposure; possible exposure < 30% probable exposure 30-90%, nearly certain exposure > 90%), with the following weights given 0; 0.15; 0.6; 0.95. Cumulative probability of exposure wa

assigned based in the combination of

probability weight and duration in years.

Exposure metrics reported

Breslow et al. (1954 Gerin et al. (1984 Buiatti et al. (1985 (juus et al (1986) choenberg et al. (19 Lerchen et al. (1987 Ronco et al. (1988 Benhamou et al. (198 (ahm et al. (1989) /lorabia et al, 1992 ezzotto and Poletto ( kolne et al. (20 alvert et al. (201) uaman et al. (201-Subtotal (I-squared = 44.1%, p = 0.03 Dunn and Weir (196 Polednak (1981) lewhouse et al. (198 **|-+**¦--Steenland et al. (1986 i 🕂 Melkild et al. (1989 Simonato et al. (1991) Kromhout et al. (1992 Danielsen et al. (1993 Sorahan et al. (1994) Park et al. (1994) Danielsen et al. (1996 van Loon et al. (1997 ustin et al. (1997) anielsen et al. (199 \_\_**\_\_** Danielsen et al. (200 ┼╍┼ Steenland et al. (200 Yiin et al. (2005) /lequellati-Hakkas et a Veolia et al. (2007 ukkala et al. (2009 Wong et al. (2017) MacLeod et al. (2017) 265 Subtotal (I-squared = 26.4%, p = 0.12) Overall (I-squared = 54.6%, p = 0.000) .5 1 Relative risk



- Welders are exposed to UVR over the full spectrum (UVA, UVB, UVC) from the welding arc, regardless of the industry or the technique used
- matter of seconds to minutes.
- welders; most reported increased risks
- proxy of UV exposure
- keratoconjunctivitis (welder's flash)<sup>(9)</sup>
- Unprotected bystanders can be exposed to UVR <sup>(10)</sup>





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Increased lung cancer risk was associated with welding in the majority of studies

>20 case-control, >20 cohorts, some overlapping, several of high-quality

Increased risks were observed regardless of welding technique, study design, occupational setting, geographic region, time period, adjustment for tobacco smoking and asbestos exposure

The WG conducted a meta-analysis to quantitatively characterize the risks and explore sources of heterogeneity (Figures 1-3)

rs included in th	-		Analyses	Ν	l <sup>2</sup>	RR (95% CI)	References of included stu
	elative sk (95% CI)	% Weight	Overall	37	54.6%	1.43 (1.31-1.55)	[9,38,40,54–56,58–70,72–74,76–83,85–89
	an (85 % 01)	Weight	Cohort	22	26.4%	1.29 (1.20-1.39)	[38,40,54–56,58–70,72–74,76]
	66 (1.36, 43.19)	0.24					[38,54–56,58,59]
	40 (1.03, 5.58)	0.93	Population-based	6	59.7%	1.27 (1.12-1.44)	[40,60–70,72–74,76]
	80 (0.91, 8.60)	0.55	Industrial	16	6.7%	1.32 (1.20-1.45)	[10,00 10,12 11,10]
	90 (0.94, 3.85)	1.27	Case-control	15	44.1%	1.87 (1.53-2.29)	[9,77–83,85–89,91,93]
2.	50 (1.12, 5.59)	1.01					[77–83,85]
	20 (1.39, 7.36)	0.96	Hospital-based	8	0.0%	1.84 (1.36-2.49)	
	93 (0.87, 9.84)	0.48	Population-based	5	13.9%	2.03 (1.61-2.57)	[86–89,91]
	42 (0.74, 2.71)	1.48	Mixed	2	70.8%	1.92 (0.91-4.08)	[9,93]
	20 (0.69, 2.08) 50 (0.82, 2.76)	1.92 1.63	Major Confounders			- (	
	10 (0.40, 3.06)	0.66	Smoking and asbestos	8	41.2%	1.17 (1.04-1.38)	[37,39,57,75,84,87,90,92]
	91 (1.03, 14.90)	0.40	-				[37,39,57,74,75,84,87,90,92,94]
	16 (1.81, 2.58)	6.43	Asbestos exposure	11	52.7%	1.22 (1.09-1.32)	[01,00,01,14,10,04,01,00,02,04]
	44 (1.25, 1.66)	7.07	Smoking	20	61%	1.34 (1.15-1.55)	[9,54,55,57,59,60,75-83,86-89,93]
2.	50 (0.98, 6.37)	0.77					157 60 77 70 93 971
1.4	87 (1.53, 2.29)	25.80	Pack/year	8	65.9. %	1.46 (1.05-2.02)	[57,60,77,79,83,87]
			Categories	3	47.6%	1.18 (0.63-2.20)	[76,89,95]
			mixed	9	41.3%	1.39 (1.13-1.71)	[9,55,59,78,80–82,88,93]
	05 (0.79, 1.39)	4.59	Type of welding				
	76 (1.07, 2.89) 13 (0.81, 1.58)	2.25 3.75	Arc welders	5	62.5%	1.23 (0.99-1.54)	[39,71,74,84,92]
	29 (0.90, 1.85)	3.47	Gas welders	5	53.2%	1.45 (1.09-1.91)	[39,71,84,90,92]
	21 (0.97, 5.02)	0.98		5	55.270	1.45 (1.09-1.91)	
	34 (1.11, 1.62)	6.23	Type of material welded	_			[40,57,68,79,86]
- 1.9	93 (1.05, 3.55)	1.63	Stainless steel	5	68.1%	1.38 (0.89-2.13)	
	50 (1.22, 5.10)	1.25	Mild steel	3	35.8%	1.44 (1.07-1.95)	[40,72,86]
	69 (1.07, 2.66)	2.56	Histologic subtype				
	38 (0.56, 3.40)	0.83	Squamous cell carcinoma	7	58.1%	1.53 (1.31-1.80)	[9,38,58,59,82,89,91]
	59 (0.14, 2.57) 86 (0.46, 1.59)	0.33 1.60	Adenocarcinoma	7	51.6%	1.35 (1.15-1.57)	[9,38,58,59,82,89,91]
	66 (0.29, 1.59)	0.98	Small cell carcinoma			1.47 (1.15-1.89)	[9,38,58,89,91]
	55 (0.79, 3.04)	1.38		5	67.1%	. ,	
	27 (0.62, 2.59)	1.25	Large cell carcinoma	2	0.0%	1.03 (0.78-1.35)	[58,91]
	22 (0.93, 1.60)	4.76	Region				
1.4	47 (1.19, 1.82)	5.71	North America	16	73.7%	1.43 (1.21-1.71)	[58-61,63,66,72,73,76,77,81,86,87,89,91,93]
	24 (0.94, 1.63)	4.69					
	67 (1.21, 2.31)	3.91	Europe	18	14.0%	1.39 (1.27-1.53)	[38,40,54–56,62,64,65,67–70,74,78–80,83
	34 (1.28, 1.40)	8.62	Setting			. ,	
	12 (0.91, 1.37) 16 (1.03, 1.31)	5.90 7.54	Shipyard	15	6.3%	1.32 (1.20-1.45)	[40,60–67,69,70,72–74,76]
	29 (1.20, 1.39)	74.20	Onipyard	10	0.570	1.52 (1.20-1.45)	
	,,		Construction	4	79.8%	1.55 (1.18-2.03)	[9,57,58,91]
1.4	43 (1.31, 1.55)	100.00	Manufacture	3	0.0%	1.33 (1.15-1.54)	[9,58,67]
					0.070	1.00 (1.10 1.01)	
			Exposure assessment met				
5 10			Questionnaire	13	54.8%	1.35 (1.18-1.54)	[38,56,58–60,77–79,81,82,85,88,93]
			Records	14	57.4%	1.46 (1.19-1.77)	[61–70,72,76,89,91]
			Expert judgment	5	48.7%	1.72 (1.05-2.83)	[55,80,83,86,87]
			JEM	3	0.9%	1.41 (1.20-1.66)	[54,73,74]

nonaryar wik et ar (in prep)

- Exposure-response associations were observed in several studies using various metrics (e.g cumulative exposure, duration of employment)
- Only 2 studies reporting on years as a welder were available for a dose-response meta-analysis (Figure 3)

WELDING AND OCULAR MELANOMA

Ocular melanoma is a very rare cancer (ASR <1 per 100,000)</p>

**Ultraviolet radiation (UVR)** emitted from tanning devices causes ocular melanoma<sup>(3)</sup>

UVR exposures are very intense within a few metres of the welding arc; exposure guidelines can be exceeded in a

### Sufficient evidence' that 'UVR from welding' causes ocular melanoma

8 partially overlapping case-control studies and 2 census based cohort studies reported on ocular melanoma in

UVR exposure from welding was not characterized in any of the studies but 2 studies reported on eye burns, a

Adjustment for other sources of UV exposure (e.g. sun exposure, sun bed use) in several studies indicated that these factors could not explain the observed associations between welding and ocular melanoma <sup>(6)(7)(8)</sup> Welders report frequent occurrence of skin erythema (sunburn) and photo-

> UVR associated with arc welding is generally much higher than other artificial UVR generating processes (e.g. germicidal lamps, photocuring, tanning lamps), and typically orders of magnitude higher than natural sunlight (solar radiation) <sup>(10)</sup>





National Cancer Institute, USA (Cooperative Agreement U01 CA33193) US NIEHS/National Toxicology Program







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