Cal/OSHA Draft Substance Summary for the June 20, 2017 HEAC Meeting

Substance name: Aluminum Metal & Insoluble Compounds

Table 1. Chemical and Physical Properties

Aluminum metal and insoluble compounds are found in multiple forms and properties. Welding fume consist mostly of aluminum oxide. The table below lists known forms but is not inclusive. Synonyms in italics

Name	Formula	CAS	MW	Density	MP, ℃[1]	BP, ℃
Aluminum	Al	7429-90-5	26.98	2.702	660.37	2467
Aluminum Oxide (*α-Alumina, corundum*)	Al_2O_3	1344-28-1	101.96	3.97	2015	2980
Aluminum Oxide (*γ-Alumina)*	Al_2O_3	1344-28-1	101.96	3.5-3.9	tr to α	
Aluminum Oxide monohydrate	$Al_2O_3 \cdot H_20$	1344-28-1	119.98	3.014	tr	
Aluminum Oxide trihydrate (*bayerite*)	$Al_2O_3 \cdot 3H_20$	1344-28-1	156.01	3.97	tr	
Aluminum hyrdroxide (*boehmite)*	AlO(OH)		59.99	3.01	tr	
Aluminum hyrdroxide (*diaspore)*	AlO(OH)		59.99	3.3-3.5	tr	
Aluminum oxyhydride	Al_2OOH		87		tr	
Aluminum hydroxide *(Aluminum trioxide*)	$Al(OH)_3$	90669-62-8	78.00	2.42	tr	
Aluminum hydroxide (*Alumina hydrate, gibbsite*	$Al(OH)_3$	21645-51-2	78.00	2.42	tr	
Aluminum Silicate (*sillimanite, andalusite, kayanite*)	$Al_2O_3 \cdot SiO_2$		162.04	3.156	1545	tr
Aluminum Silicate (*mullite)*	$3Al_2O_3 \cdot 2SiO_2$		426.05	3.156	tr	
Magnesium Aluminum Silicate (*pyrope*)	$Mg_3Al_2(SiO_4)_3$		403.1	3.78	tr	
Magnesium Aluminum Silicate (*colerainite*)	$MgAl_2(SiO_4)_2$	12511-31-8	262.4		tr	
Sodium Aluminum Silicate amorphous	variable composition	1344-00-9			tr	
Sodium Aluminum Silicate (synthetic zeolite)	$14SiO_2 \cdot Al_2O_3 \cdot$ $Na_2O \cdot 3H_2O$, ($Na_2Al_2Si_{14}O_{32} \cdot 3H_2O$)	1344-00-9			tr	
Aluminum chloride hydroxide (aluminum trichloride hexahydrate)	$AlCl_3 \cdot 6H_20$	98493-35-7	241.43	2.398	d	

Notes: 1. tr = transitions on heating to another form or arrangement of atoms

d = decomposes on heating

Table 2. Physical State and Appearance

Name	Bulk crystalline form index of refraction, η	Film	Particle
Aluminum	silvery, white metal	silvery, white metallic 0.1 - 1000 µm thickness	10 - 1000 µm powder 0.1 - 30 µm dust 0.001 - 10 µm fume 0.01 - 1 µm smoke
Aluminum Oxide *α-Alumina* *corundum*	solid crystal, colorless rhombic η = 1.760	2 - 3 µm white on surface of aluminum	0.001 - 0.1 µm nano particle 10 - 1000 µm white powder 0.1 - 10 mm white granual
Aluminum Oxide *γ-Alumina*	White micro crystal, η = 1.7		
Aluminum Oxide monohydrate	solid crystal, colorless rhombic η = 1.624		10 - 1000 µm white powder
Aluminum Oxide trihydrate *bayerite*	White micro crystal, η = 1.583		10 - 1000 µm white powder
Aluminum hyrdroxide *boehmite*	white ortho rhombic micro crystal		10 - 1000 µm white powder
Aluminum hyrdroxide *diaspore*	colorless rhombic crystals		10 - 1000 µm white powder
Aluminum oxyhydride			
Aluminum hydroxide Aluminum trioxide	white monoclinic crystals		10 - 1000 µm white powder
Aluminum Silicate *sillimanite* *andalusite* *kayanite*	White rhombic crystal, η = 1.66		162.04
Aluminum Silicate *mullite*	White colorless rhombic crystal, η = 1.638, 1.642, 1.653		10 - 1000 µm white powder
Magnesium Aluminum Silicate *pyrope*	Red rhombic dodecahedral η = 1.74		
Sodium Aluminum Silicate amorphous	variable composition		
Sodium Aluminum Silicate synthetic zeolites	variable composition		
Aluminum chloride hydroxide aluminum trichloride hexahydrate	White colorless rhombic crystal η = 1.6		deliquescent

USES / APPLICATIONS / OCCURRENCE / EXPOSURE

Aluminum is the third most abundant element on the planet, comprising 8.3% of the earth's crust. In nature it occurs primarily as complex silicates. Aluminum is amphoteric, forming both aluminum salts and aluminates.

Aluminum metal has thousands of uses where light- its light weight, and low density, is the key attraction. Aluminum metal also finds applications where corrosion resistance is a key attribute. Pure aluminum is highly malleable and ductile allowing it to be drawn into wire, rolled into sheets and films of almost any thickness and deposited onto almost any surface. Pure aluminum is a good conductor of electricity and heat. Aluminum is alloyed with many different elements giving it a wide range of properties in terms of strength, density, melting temperature and corrosion resistance. Exposures occur during mining the ore, production of aluminum by electrolytic reduction of the oxide, cold cutting, sawing, grinding; polishing the metal, welding and flame cutting. Aerosol particle size, shape, and composition is dependent on the base metal and process.

Aluminum oxide in bulk form can be gem-quality crystal. Most aluminum oxide is used in particle form in abrasives, ceramics, catalysts, cosmetics. Exposures can occur in the handling of the material and in the use of the product.

Insoluble aluminum compounds, including oxides, hydroxides, silicates, and chlorhydroxides, are used in personal hygiene products, cosmetics, pharmaceuticals and food additives. Aluminum compounds make up the active ingredient in deodorants, antiperspirants, antacids, analgesics, and disinfectants. Aluminum compounds are used as flocculating and coagulating agents in water purification and chemical synthesis

Occupational Exposure Limits

Title 8 PEL (1989):

Alumina; see Particulates not otherwise regulated		
Aluminum, alkyls (not otherwise classified)	--	**2 mg/m³ TWA**
Aluminum soluble salts	--	**2 mg/m³ TWA**
Aluminum metal and oxide	--	
Total dust	--	**10 mg/m³ TWA**
Respirable fraction(n)	--	**5(n) mg/m³ TWA**
Aluminum pyro powders	--	**5 mg/m³ TWA**
Aluminum welding fumes	--	**5 mg/m³ TWA**

Table 3. Proposed Exposure Guidelines

Name	Current OSHA PEL from Table Z-1[1] mg/m³	Current Cal/OSHA PEL from Table AC-1 mg/m³	Proposed PEL from ACGIH TLV mg/m³
Aluminum	15 TWA T 5 TWA R	10 TWA T 5 TWA R	1 TWA R
Aluminum metal flake	15 TWA T 5 TWA R	10 TWA T 5 TWA R	no guideline
Aluminum powder coated with oxidation inhibiting oil	15 TWA T 5 TWA R	10 TWA T 5 TWA R	no guideline
Aluminum Oxide *α-Alumina* *corundum*	15 TWA T 5 TWA R as PNOR	10 TWA T 5 TWA R	1 TWA R[2] 10 TWA T or 15 TWA I
Aluminum Oxide *γ-Alumina*	15 TWA T 5 TWA R as PNOR	10 TWA T 5 TWA R	1 TWA R[2] 10 TWA T or 15 TWA I
Aluminum Oxide monohydrate	15 TWA T 5 TWA R as PNOR	10 TWA T 5 TWA R	1 TWA R
Aluminum Oxide trihydrate *bayerite*	15 TWA T 5 TWA R as PNOR	10 TWA T 5 TWA R	1 TWA R
Aluminum hyrdroxide *boehmite*	15 TWA T 5 TWA R as PNOR	10 TWA T 5 TWA R	1 TWA R
Aluminum hyrdroxide *diaspore*	15 TWA T 5 TWA R as PNOR	10 TWA T 5 TWA R	1 TWA R
Aluminum oxyhydride		10 TWA T 5 TWA R	1 TWA R
Aluminum hydroxide Aluminum trioxide		10 TWA T 5 TWA R	1 TWA R

Name	Current OSHA PEL from Table Z-1[1] mg/m³	Current Cal/OSHA PEL from Table AC-1 mg/m³	Proposed PEL from ACGIH TLV mg/m³
Aluminum Silicate *sillimanite* *andalusite* *kayanite*	15 TWA T 5 TWA R as PNOR	10 TWA T 5 TWA R	1 TWA R
Aluminum Silicate *mullite*	15 TWA T 5 TWA R as PNOR	10 TWA T 5 TWA R	1 TWA R
Magnesium Aluminum Silicate *pyrope*			1 TWA R
Sodium Aluminum Silicate amorphous		2 TWA T	no guideline
Sodium Aluminum Silicate synthetic zeolites		10 TWA T 5 TWA R	1 TWA R
Aluminum chloride hydroxide aluminum trichloride hexahydrate		10 TWA T 5 TWA R	1 TWA R
Aluminum pyro powders		5 TWA T	1 TWA R
Aluminum nano powders		no guideline	no guideline
Aluminum welding fumes		5 TWA R	1 TWA R
Aluminum alkyl compounds NOS		2 TWA T	no guideline
Aluminum soluble salts		2 TWA T	no guideline
Aluminum stearate		10 TWA T	
Aluminum distearae		10 TWA T	
Aluminum tristearate		10 TWA T	

Note 1: T = Total
R = Respirable Fraction
I = Inhalable

Note 2: The choice of sampling respirable or total/inhalable depends on the source of the particulate matter. If the MMAD is greater than 7 µm, use total or ihalable criterion; if the MMAD is less than 7 µm, use respirable sampling and criterion. If the MMAD is not known, both respirable and total/inhalable should be sampled.

NIOSH REL: 5 mg/m³ TWA
DFG (Germany): 4 mg/m³ TWA inhalable / 1.5 mg/m³ TWA respirable fraction
Sweden: 4 mg/m³ TWA respirable fraction / 10 mg/m³ TWA total
UK: 4 mg/m³ TWA respirable fraction / 10 mg/m³ TWA inhalable

Other recommendations

Source and date	Recommendations	Basis/source/ref(s)	Discussion and Assessment
OEHHA REL	Not listed		
Prop 65	Not listed		
NTP	No evidence		
EPA	Not assessed		
IARC	Not classified		
EU	Not Established		

Peer-reviewed journal articles used for proposed PEL

Piggot 1981

Study type/Endpoint: 90-week rat inhalation study; respiratory effects, fibrosis, cancer
Method: Animals exposed to 2.5 mg/m^3 of aluminum fiber (median diameter – 3.0 microns) in inhalation chamber for 86 weeks. Study terminated at 128 weeks with interim sampling to evaluate
Results: Reaction was generally confined to the presence of groups of pigmented alveolar macrophages. Minimal aveolar epithelialization was observed but not evident after 106 weeks. No evidence of fibrosis. In a few cases fibers observed in the nasal passage were associated with slight irritation of nasal mucosa with minimal focal necrosis.
Discussion/ assessment: This singe-dose study with aluminum fibers observed very little respiratory effects. The LOAEL was set at 2.5 mg/m^3. The particle size was very homogeneous and considerably larger (3 microns) than welding particle fumes (< 1 µm).

Sjogren, 1985

Study Type: cross-sectional
Methods: Three welder groups (aluminum, stainless steel and railroad track) and controls were evaluated for respiratory symptoms and pulmonary effects. Median exposure welding time for Al welders was 5 years (range: 1-24). Controls were non-welding workers. Welders and controls were matched for smoking. Symptoms were assessed by questionnaire and effects by forced vital capacity and forced expiratory volume. Total particulate

welding fumes were measured gravimetrically and ranged from 0.5 to 4.5 mg/m^3 (tungsten inert gas welding) and 7 – 42 mg/m^3 (metal inert gas welding).
Results: Al welders reported greater frequency of bronchitis and respiratory symptoms but not significantly different from controls. Within welders, symptoms were significantly different between welders exposure to high and low levels of ozone (p =0.03). There were no significant differences in FVC and FEC between welders and controls.
Discussion/Assessment: What respiratory effects observed in the study were likely due to the particle load and ozone generated during welding,

Hänninen H 1994

Study: cross-sectional
Method: Seventeen male welders with a mean age of 37 (range 24 - 48) years and a history of four years of metal inert-gas welding on aluminum were evaluated by tests for simple reaction time, psychomotor speed, visual and spatial ability, memory tests, verbal ability, subjective mood and quantitative electroencephalography (QEEG). Urine and serum Al were determined. For 11 welders, urinary aluminum was the mean of four weekly urine samples taken during a summer vacation while for the other six subjects, the serum and urine samples were taken on the morning of the examination day. Control responses were compared to historic average values from other studies involving skilled and semiskilled chemically exposed workers and workers with slight neurotoxic exposure.
Results: The urinary-Al concentrations ranged from 0.9 to 6.1 µmol /L (median 2.4, mean 2.8). All neurological test results fell within the average or good range of the historic values. However, correlations between the test scores and exposure parameters showed a negative association between the four memory tests and exposure to aluminum and a positive association between the variability (standard deviation) of visual reaction times and U-Al. The QEEG power parameters recorded from the frontal and frontotemporal regions of the brain correlated with the Al exposure parameters.
Discussion/Assessment: Though the numbers are small, the results in this study are consistent with other studies showing neurological decrements with urinary Al levels. Urinary Al levels were negatively correlated with age and the group was highly homogeneous so correlations between test results and urinary Al levels are convincing.

Sjogren, 1996

Study type: cross-sectional, retrospective
Methods: Comparison of symptom questionnaire response and psychological/psychomotor testing of Al-welders with self-declared non-Al welders.
Results: Al exposed workers (38, mean age = 39, mean years welding = 17.1) had urinary Al levels of 0.21 µmol/L (0.04 - 2.5) whereas controls had levels of 0.03 µmol/L (ND – 0.26) to controls (39, mean age = 41, mean years welding = 13.8). Information on exposure time was obtained from a questionnaire. The exposure to particles in the breathing zone of the welders was surveyed in the mid-1970s. The median exposure was 10 mg/m^3 during Al metal inert gas (MIG) welding. Al workers differed from controls in 2 of 28 questionnaire responses, 4 of 20 psychological tests and 1 EEG measure. When controls and welder groups were combined and categorized into percentiles by Al urinary levels (50th :< 0.08 µmol/L; 50th-75th: 0.08 – 0.23 µmol/L; 75th: > 0.23 µmol/L ug/l, 75th median = 0.59 µmol/L) three response/test comparisons had a significant dose-response effect. With this grouping, the 75th percentile was significantly different from the other two groups in its response.
Discussion/Assessment: the study has limitations due to the retrospective exposure assessment and confounders (other metals in urine) but the significant dose-response relationship between urinary levels and symptoms/effects supports the role of Al as a cause in Al-exposed workers. All Al welders in this study had at least 5 years welding and the mean was 17. The study appears to have been done on the past welding experience of the workers so Al levels likely represent the accumulated body burden from past exposure.

Akila, 1999

Study type: cross-sectional
Method: A comprehensive neuropsychological examination was undertaken to assess psychomotor function, simple visual reaction time, attention related tasks, verbal and visual or visuospatial abilities as well as verbal and visual learning and memory of asymptomatic aluminum welders and a reference group of mild steel welders. Workers (mean age = 38.4) from 12 sites were classified into three groups based on urinary aluminium concentrations: reference (<1.0 µmol/L), low exposure (1.1–4.0 µmol/L) and high exposure (>4.1 µmol/L). The reference value for urinary aluminum in occupationally non-exposed populations was 0.6 µmol/L. Mean welding years not reported but workers with up to 25 years welding were included.
Results: Performance on 16 cognitive tests compared between groups. Of the 16 tests conducted, 4 showed significant ($p<0.05$) exposure-response relations and group effects (high dose group).
Discussion/Assessment: The study implemented a more extensive array of cognitive tests to assess specific cognitive domains and claim results are consistent with expected neurological deficits. The study concluded that based on the tasks showing impairments, the involvement of time-limited processing in visuospatial tasks requiring working memory demands is impacted by Al.

Riihimaki, 2000

Study Type: Cross-sectional
Method: Nation-wide survey identified 10 companies that had been conducting Al welding for many years. 90 participants from 9 workplaces were administered symptom surveys (Profile of Mood States), neuropsychological tests (psychomotor, reaction time, attention, verbal/visual abilities and memory/learning) and quantitative electroencephalography (QEEG). Exposure was assessed by questionnaire and measurement of urinary Al. Controls were non-Al welding workers from within the same companies. Three exposure groups were established based on urinary Al levels: controls (range: 0.1-1.2 µmol/L) low exposure (0.3 – 5.7 µmol/L, 1-16 years welding) and high exposure (3.2 – 27.6 µmol/L, 4 – 23 years welding).
Results: In the population of aluminum MIG welders, the U-Al ranged from 0.3 to 27.6 µmol/L. Among the current mild-steel welders, the corresponding ranges were 0.04-0.19 µmol/L and 0.1-1.6 µmol/L, respectively. For 1/3 of the aluminum welders, the exposure had continued over 10 years with a maximum of 23 years. Grouping symptom responses into 4 categories: fatigue, memory/concentration differences, emotional lability and sensory/motor symptoms, significant differences ($p <0.05$) between controls and the high exposure group were seen for the first 3 categories. The biggest difference was found in memory and concentration difficulties, and a more moderate difference was found for fatigue and emotional lability. For sleeping disturbances and sensory and motor symptoms the difference was not significant. Significant impairments of neuropsychological function between controls and the high exposed group were found in 5 of the 6 tests ($P<0.05$ for all). 12 of 21 age-adjusted correlations between urinary Al and the neuropsychological tests were significantly negatively correlated. For QEEG, diffuse EEG abnormalities were observed in 13 subjects. All of them had mild abnormalities. Five of them belonged to the low-exposure group, 8 belonged to the high-exposure group, and the exposure-related linear trend of change among the groups was significant.
Discussion/Assessment: The subjective symptom inquiry showed exposure-related increases in memory and concentration problems, fatigue, emotional disturbances indicative of mild depression, and certain sensory and motor symptoms. Overall, the complaints associated with Al exposure seemed to focus on certain core symptoms rather than being expressions of a more general distress. Association between the neuropsychological tests and Al exposure were less strong. In the visually interpreted EEG, diffuse nonspecific abnormalities were observed in the low- and high-exposure groups, whereas epileptiform abnormalities were present mainly in the high-exposure group. The threshold of aluminum body burden implying an adverse effect thus seemed to correspond to 4-6 µmol/L of Al in urine.

Bast-Petterrsen, 2000

Study type: cross-sectional
Methods: Twenty aluminum welders (mean age 33), who had been exposed to Al for an average of 8.1 years (range 2-21), were tested for tremor and reaction time and screened for neuropsychiatric symptoms in a cross-sectional study. The welders' median urinary Al concentration was 1.5 µmol/L (range 0.7-4.8). Al in air, measured inside the respiratory protection, was 0.9 mg/m^3 (range 0.6- 3.8). The welders were compared with twenty construction workers matched for age.
Results: Welders reported more symptoms than referents did (median 2 vs. 1; P = 0.047). Welders performed better on tremor test and psychomotor tests than controls. There was a statistically significant relation between longer reaction times and Al in air among welders. Also, hand steadiness in welders was inversely correlated with years welding.
Discussion/Assessment: Welders performed better on tests than controls (construction workers). This study indicates a slight exposure-related effect on the studied parameters, i.e., reaction time, steadiness of hand, and neuropsychiatric symptoms all declined with years welding. However, the results indicate that these welders were not clinically impaired in terms of steadiness of hand or reaction time compared to clinical values.

Buchta, 2003; Kiesswetter, 2009

Study type: longitudinal with matched controls – automobile welders
Method: Study of automobile welders over 4 years with assessments on 98 Al welders (Al welding years 8.8 ± 1.7) and 50 controls. Symptoms, neurobehavioral and psychomotor performance tests collected at 3 examination points (0, 2 and 4 years) were compared. Respirable dust samples and urine samples collected. Loss to enrollment over the 4-year study was 6%
Results: Median respirable dust exposure from the three sampling events were 0.8 ± 0.9, 0.5 ± 0.3, and 0.7 ± 0.3 mg/m^3 resulting in median urinary-Al concentrations of 0.52 ± 0.35 µmol /L, 0.48 ± 0.35 µmol /L, and 0.22 ± 0.27 µmol/L, respectively. No significant differences in the 15 psychomotor performance and other neurobehavioral tasks were seen between welders and non-welder, with the exception of simple reaction time. Reaction time increased in welders over the four year period but not in controls (p =0.015). The interaction term for examination and exposure was not significant but for examination and age was significant (P<0.001).
Discussion/Assessment: the exposure interval of this study is short – 4 years – and limits the study's ability to discriminate an effect of Al exposure. Regression analysis showed that urinary-Al was only a predictor of reaction time in models in that all groups, not just the exposed workers, were included, suggesting Al exposure alone was not the sole cause of the effects.

Buchta, 2005; Kiesswetter, 2007

Study type: longitudinal with matched controls - truck/trailer welders.
Method: Study of automobile welders over 4 years with assessments on 44 Al welders (Al welding years 15) and 37 controls. Using same methods as Buchta, 2003, symptoms, neurobehavioral and psychomotor performance tests collected at examination points 2 years apart were compared to controls. Respirable dust samples and urine samples collected. Loss to enrollment over the 4-year study was 52%
Results: Median respirable dust exposure from the three sampling events were 5.6 mg/m^3 4.5 mg/m^3 and 6.8 mg/m^3 resulting in median urinary-Al concentrations of 1.34 µmol /L and 1.61 µmol/L, and 0.95 respectively. Neurobehavioral symptoms declined in both groups and were not significantly different (Welders = 1.9; Controls = 1.6). No significant group differences were detected between welders and controls for psychomotor tests (steadiness, line tracing, tapping or aiming). Exposed and controls did not differ significantly for simple reaction time. The interaction between "examination and exposure" was nonsignificant (p=0.11). In the cognitive tests, welders performed significantly less than controls for the Block design and forward digit span test.
Discussion/Assessment: This study was a done in parallel with Buchta, 2003 with a group of truck/train welders with significantly higher Al exposure (5.6 mg/m^3 total dust). A few neurological effects were detected but not

consistently as with the previous study. The authors acknowledge that the interval between examinations (2 years) and the drop in participation of the exposed welders (from 44 to 20) may not have been sufficient to detect differences of neurobehavioral trends between exposed and controls.

HEAC Health-based assessment and recommendation

Effects of Al on the brain are the most sensitive toxicological endpoint, however Al brain levels that are associated with neurological disease are not characterized. There are no good animal models for the cognitive and memory effects of Al seen in humans and the most informative data comes from epidemiological studies of Al urinary levels in aluminum welders and neurological deficits assessed through symptom questionnaires and cognitive testing. Al urinary levels are a function of Al air concentration and welding years but an absolute relationship between these factors and neurological effects is not known though Al welding of >15 years seems implicated with significant neurological effects. The reviewed studies indicate that after at least 4 years of exposure at or below occupational exposure levels, marginal neurological deficits are observed in Al welders and are associated with exposure. In several of these studies, many of these deficits fall within or above the range seen in controls or populations average however given a significant dose-response has been established in several of these studies it can be concluded that Al contributed to the neurological deficits seen in the welders.

Using studies in which Al air concentration and Al and welding years are recorded brackets exposure conditions from 0.5 – 5.6 mg/m^3 for Al air concentrations and 4.0 – 17 years for welding years. Several of the studies overlap in this range of exposure conditions so their findings can be compared. The welders in Bast-Pettersen 2000 and Buchta 2003 experienced roughly the same exposure level (1 mg/m^3) with less than 10 years welding years (8 and 8.8). Urinary Al levels are similar and both studies found an increase in simple reaction time. In the studies with longer exposure intervals (mean>15 years; Akila, 1999; Sjogren, 1996, possibly Riihimaki, 2000) there is stronger evidence for an association between Al exposure in that dose-response relationships between urinary Al levels and neurological deficit are significant. Unfortunately these longer-term studies did not measure Al air levels so it cannot be determined what level of Al exposure produced the urinary Al levels. The longitudinal studies of Al welders by Buchta 2003 and Buchta 2005 provide well-characterized exposure estimates for welders with moderate to high years welding (8 and 15) yet could only detect inconsistent neurological deficits in the welders. Unfortunately Buchta 2005 experienced a high drop in welder participation that makes the findings of that study problematic. Buchta 2003 experienced virtually no drop in participation and with multiple measures detected a significant drop in simple reaction time in welders with multiple measures over 6 years.

Given that Al accumulates in the body from chronic workplace exposure, years welding is a prime determinant of risk of acquiring neurological effects of aluminum. Using findings of the studies cited above a matrix can be prepared of years welding, urinary Al levels and total dust concentrations (for a subset of studies) can be prepared. All studies established some level of neurological deficit at a result of Al exposure which is to be expected as these effects are on a continuum of neurological decline that would occur in a time-dependent manner. Riihimaki, Sjogren and Akila had the cohorts with the greatest years welding and found the most number of significant impacts in welders. The Buchta studies found minimal neurological impacts but these studies were conducted with personal protective equipment (forced air ventilation in the welding helmut) and report some of the lowest urinary Al levels of the studies. Mean urinany Al levels in Buchta 2003 are comparable with Bast-Pettersen where Al air measurements were obtained inside the personal protective equipment.

Study	**Years welding**	**Urinary Al (µmol/L, median)**	**Al air** (mg/m^3)

Hänninen, 1994	4	2.4 (0.9 – 6.1)	
Sjogren, 1996	15	0.81 (0.04 – 2.5)	
Akila, 1999	10-23	0.46/2.25/9.98	
Bast-Pettersen, 2000	8.1	1.54 (0.7 – 4.8)	0.9
Riihimaki, 2000	10-23	0.4/1.8/7.1	
Buchta 2003	8.8	0.52/0.48/0.22	0.8/0.5/0.7
Buchta 2005	15	1.34/1.61/0.95	5.6/4.5/6.8

Recommendation: A PEL of 1.0 mg/m^3 is recommended based on urinary Al levels associated with the onset of neurological effects. Air concentrations in Bast-Pettersen, 2000 and Buchta 2003 are comparable and while the studies did not observe definitive differnences between welders and controls, both studies found a decline in simple reaction time in welders that indicates a neurological effect of Al.

Usage information: EPA TSCA Chemical Data Reporting (CDR), EPA Toxics Release Inventories (TRI)), other sources

In 2015, there were 159 TSCA CDR records for aluminum (usage in excess of 25,000 lbs) in U.S. Of these, 9 were in California. In 2016 there were 336 TRI records for aluminum of which 15 were in California.

Measurement information

OSHA Method: OSHA ID -121, OSHA ID-109SG, OSHA ID-198SG
NIOSH Method: 7013, 7300, 7301, 7302, 7303, 7304, 7306
Estimated LOD/LOQ: each method has a different LOD/LOQ many of which can measure down to from 0.05 mg/m^3 to 0.001mg/m^3.
Measurement issues: Choosing the best method for the form of aluminum to be encountered.

Recommended Workplace Controls

Providing suitable control measures such as ventilation to control exposure can be accomplished using existing equipment as most systems have the ability to control to the proposed levels.

Economic Impact Analysis/Assessment

The Division has made a determination that this proposal is not anticipated to result in a significant, statewide adverse economic impact directly affecting businesses, including the ability of California businesses to compete with businesses in other states. This proposal will not have any effect on the creation or elimination of California jobs nor result in the creation or elimination of existing businesses or affect the expansion of existing California businesses. The Division anticipates that any potential costs will be balanced by avoiding or minimizing the costs inherent in workers' compensation claims, lost work time, and productivity losses that would have been caused by exposure related illness of employees.

The PEL proposed is consistent with recent scientific findings, of which professional health and safety staff and consultants of these employers and others with significantly exposed employees should be aware. Many of these entities already seek to control employee exposures to substances to levels below existing PELs in the interest of business continuity and minimization of tort and workers compensation liability.

Setting a Permissible Exposure Limit for aluminum that is up-to-date and consistent with current scientific information and state policies on risk assessment will send appropriate market signals to employers with respect to the costs of illness and injury, which chemicals can impose on workers and their families, the government, and society at large. With appropriate market signals, employers may be better able to choose chemicals for use in the workplace that impose less of a burden on workers and society. There are no anticipated benefits to the state's environment.

The economic benefits from the proposed PEL will result primarily from reduced health risk among exposed workers.

References cited

Akila R; Stollery BT; Riihimaki V, 1999. Decrements in cognitive performance in metal inert gas welders exposed to aluminum. Occup. Environ. Med. 56(9):632-639

Bast-Pettersen R, Skaug V, Ellingsen D, Thomassen Y, 2000. Neurobehavioral Performance in Aluminum Welders American Journal of Industrial Medicine 37:184-192

Buchta M, Kiesswetter E, Otto A, Schaller KH, Seeber A, Hilla W, Windorfer K, Stork J, Kuhlmann A, Gefeller O, Letzel S. 2003. Longitudinal study examining the neurotoxicity of occupational exposure to aluminium-containing welding fumes. Int Arch Occup Environ Health. 76(7):539-48

Buchta AM, Kiesswetter BE, Schäper BM, Zschiesche CW, Schaller DKH, Kuhlmann AA, Letzel AS. 2005. Neurotoxicity of exposures to aluminium welding fumes in the truck trailer construction industry. Environ Toxicol Pharmacol. 19(3):677-85.

Hänninen H, Matikainen E, Kovala T, Valkonen S, Riihimäki V. Internal load of aluminum and the central nervous system function of aluminum welders. Scand J Work Environ Health. 1994 20(4):279-85.

Kiesswetter E, Schäper M, Buchta M, Schaller KH, Rossbach B, Kraus T, Letzel S. Longitudinal study on potential neurotoxic effects of aluminium: II. Assessment of exposure and neurobehavioral performance of Al welders in the automobile industry over 4 years. 2009 Int Arch Occup Environ Health. 82(10):1191-210.

Kiesswetter E, Schäper M, Buchta M, Schaller KH, Rossbach B, Scherhag H, Zschiesche W, Letzel S 2007. Longitudinal study on potential neurotoxic effects of aluminium: I. Assessment of exposure and neurobehavioural performance of Al welders in the train and truck construction industry over 4 years.
Int Arch Occup Environ Health. 81(1):41-67

Riihimäki V; Hänninen H; Akila R; Kovala T; Kuosma E; Paaklulainen H; Valkonen S; Engström B, 2000. Body burden of aluminum in relation to central nervous system function among metal inert-gas welders. Scand. J. Environ. Health 26(2):118-130.

Sjogren B; Iregren A; Frech W; Hagman M; Johansson L; Tesarz M; Wennberg A; 1996. Effects on the nervous system among welders exposed to aluminium and manganese. Occup. Environ. Med. 53(1):32-40.

Sjogren B, Ulfvarson. Respiratory symptoms and pulmonary function among welders working with aluminum, stainless steel and railroad tracks U Scand J Work Environ Health 1985; 11(1) 27-32