



AIOH POSITION PAPER

Inorganic Lead and Occupational Health Issues

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AUTHORISATION

This position paper has been prepared by the AIOH Exposure Standards Committee and authorised by the AIOH Council.

A handwritten signature in cursive script, reading 'Sharan R. Johnson', is positioned below the authorisation text.

President AIOH

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Australian Institute of Occupational Hygienists Inc (AIOH)

The Australian Institute of Occupational Hygienists Inc. (AIOH) is the association that represents professional occupational hygienists in Australia. Occupational hygiene is the science and art of anticipation, recognition, evaluation and control of hazards in the workplace and the environment. Occupational hygienists specialise in the assessment and control of:

- Chemical hazards (including dusts such as silica, carcinogens such as arsenic, fibrous dusts such as asbestos, gases such as chlorine, irritants such as ammonia and organic vapours such as petroleum hydrocarbons);
- Physical hazards (heat and cold, noise, vibration, ionising radiation, lasers, microwave radiation, radiofrequency radiation, ultra-violet light, visible light); and
- Biological hazards (bacteria, endotoxins, fungi, viruses, zoonoses).

Therefore the AIOH has a keen interest in the potential for workplace exposures to **inorganic lead**, as its members are the professionals most likely to be asked to identify associated hazards and assess any exposure risks.

The Institute was formed in 1979 and incorporated in 1988. An elected governing Council, comprising the President, President Elect, Secretary, Treasurer and three Councillors, manages the affairs of the Institute. The AIOH is a member of the International Occupational Hygiene Association (IOHA).

The overall objective of the Institute is to help ensure that workplace health hazards are eliminated or controlled. It seeks to achieve this by:

- Promoting the profession of occupational hygiene in industry, government and the general community.
- Improving the practice of occupational hygiene and the knowledge, competence and standing of its practitioners.
- Providing a forum for the exchange of occupational hygiene information and ideas.
- Promoting the application of occupational hygiene principles to improve and maintain a safe and healthy working environment for all.
- Representing the profession nationally and internationally.

More information is available at our website – <http://www.aioh.org.au>

Consultation with AIOH Members

AIOH activities are managed through committees drawn from hygienists nationally. This position paper has been prepared by the Exposure Standards Committee, with comments sought from AIOH members generally and active consultation with particular members selected for their known interest and/or expertise in this area. Various AIOH members were contributors in the development of this position paper. Key contributors included: Kevin Hedges and Robert Golec.

Twenty-eighth AIOH Council

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List of Abbreviations and Acronyms

ACGIH	American Conference of Governmental Industrial Hygienists
AIOH	Australian Institute of Occupational Hygienists
AS/NZS	Australian New Zealand Standard
ASCC	Australian Safety and Compensation Council
BEI	biological exposure index
EPA	Environmental Protection Authority
ES	exposure standard
ES-TWA	exposure standard, time weighted average
HEPA	high efficiency particulate air filters
HSE	Health and Safety Executive (United Kingdom)
IARC	International Agency for Research on Cancer
IOM	Institute of Occupational Medicine
ISO	International Standards Organization
LEV	local exhaust ventilation
L	litre
LOAEL	lowest-observed-adverse-effect-level
m	metre
mg/m ³	milligrams (10 ⁻³ gm) per cubic metre
μ	micro-, (10 ⁻⁶) as in micrometre
μg	microgram (10 ⁻⁶ gram)
mL	millilitre (10 ⁻³ litre)
NATA	National Association of Testing Authorities
NES	national exposure standard
NHMRC	National Health & Medical Research Council
NIOSH	National Institute for Occupational Safety and Health
NOHSC	National Occupational Health and Safety Commission

*Australian Institute of Occupational Hygienists Inc
Position Paper on Lead*

OHS	occupational health & safety
PAPR	powered air purifying respirator
PbB	blood lead or lead in blood
PPE	personal protective equipment
ppm	parts per million (1 in 10^{-6})
ppb	parts per billion (1 in 10^{-9})
RPE	respiratory protection equipment
STEL	short term exposure limit
TLV	threshold limit value
TWA	time weighted average
WHO	World Health Organization

AIOH Position on Inorganic Lead and its Potential for Occupational Health Issues

Summary

The majority of Legislation in Australia for the control of lead exposure in the workplace is modelled on the *National Standard Control of Inorganic Lead at Work* (NOHSC: 1012) 1994. The AIOH believes that this standard is outdated and does not provide adequate protection to “nearly all workers” and especially females of reproductive capacity. Some multi-national companies have lowered their exposure limits in light of current research. In addition the International Agency for Research on Cancer (IARC) has changed the category from possible to a probable human carcinogen (Group 2A). This should provide impetus for lead exposure to be reduced further to levels as low as reasonably practicable (ALARP).

Blood lead (PbB) should be used as the primary indicator of exposure from both airborne lead as well as sources based on personal hygiene (eg eating and smoking). Air monitoring should be considered, complementary, to evaluate the effectiveness of controls for airborne lead. To reduce potential exposure to airborne lead, an exposure standard of 0.1 mg/m³ (TWA) is recommended. Where there is potential for lead in air to exceed 0.05 mg/m³, or where a risk assessment indicates a need, a blood lead monitoring programme is required.

The AIOH recommends that where there is a likelihood for males/females and females (of reproductive age) to reach PbB levels of ≥ 20 µg/dL and ≥ 10 µg/dL respectively, a system should be implemented to manage and control exposures. A transfer level of ≥ 30 µg/dL and ≥ 10 µg/dL should be implemented to transfer males / females (not of reductive age) and females (of reproductive age) respectively to a non lead risk job.

What is Inorganic Lead?

Lead (Pb) is obtained by the smelting of ores containing lead sulphide (galena) or sulphate or carbonate ores (Firth, 2007). With atomic number 82, atomic weight 207.19 and a specific gravity of 11.34, it is a bluish or silvery grey metal with a melting point of 327.5 °C and a boiling point at atmospheric pressure of 1740 °C. Lead has four naturally occurring isotopes with atomic weights 208, 206, 207 and 204 (in decreasing order of abundance).

Despite the fact that lead has four electrons on its valence shell, its typical oxidation state is +2 rather than +4, since only two of the four electrons ionize easily.

How do we Measure it?

Two types of monitoring are used:

- Air monitoring in the workplace for lead; and
- Biological monitoring of the worker for blood lead level.

Sampling

Air monitoring using an inhalable dust sampler is the common method for measuring lead particulate in air. The Australian Standard *AS 3640-2004: Workplace atmospheres - Method for sampling and gravimetric determination of inhalable dust* should be used. Pickford and Davies (2007) provide detail of sampling for dust and other aerosols. When monitoring for lead in blood (PbB), the Australian Standard AS 2636 (Standards Australia 1994) should be used for sampling.

Analysis – inhalable lead

Methods typically used for the measurement of particulate inorganic lead in air samples include flame atomic absorption spectrometry (AAS), inductively coupled plasma-atomic emission spectroscopy (ICP-AES) and X-ray fluorescence (XRF). Some methods are as follows:

- HSE - Methods for the determination of hazardous substances (MDHS).¹
- MDHS 6/3 Lead and inorganic compounds of lead in air - Laboratory method using flame or electrothermal atomic absorption spectrometry.
- MDHS 91. Metal and metalloids in workplace air by X-ray fluorescence spectrometry.
- MDHS 99 Metals in air by ICP-AES.
- NIOSH methods² - Lead by:
 - Flame AAS Method 7082.
 - GFAAS - Method 7105.
- NIOSH - Elements by ICP:
 - Nitric/Perchloric Acid Ashing - Method 7300.
 - Aqua Regia Ashing –Method 7301.
 - Hot Block/HCl/HNO₃ Digestion - Method 7303.
- OSHA - Metal & Metalloid Particulates:
 - in Workplace Atmospheres (Atomic Absorption) – Method 121.
 - in Workplace Atmospheres (ICP Analysis) – Method 125G.
 - from Solder Operations (ICP Analysis) Method 206.

Analysis – lead in blood

Blood lead levels are normally expressed in micrograms lead per 100mL or decilitre (µg/dL). According to the ACGIH (2001), analysis of PbB by graphite furnace atomic absorption spectrometry, anodic stripping voltametry, or inductively coupled plasma-mass spectrometry are sufficiently sensitive for lead blood levels below 30µg/dL. Analysis by AS 2411 (Standards Australia 1993a) and AS 4090 (Standards Australia 1993b) are recommended.

Some other test indicators of the biological effect of lead, such as zinc protoporphyrins (ZPP) and free erythrocyte protoporphyrins (FEP), both sensitive measures of the effect of lead on haemoglobin synthesis, can be used to supplement the basic blood lead measurement, but they are not generally used in routine surveillance. There is also a lot of individual variability in the protoporphyrin response to lead absorption (Wooller, 2003).

¹ Available from <http://www.hse.gov.uk/pubns/mdhs/index.htm>

² Available from <http://www.cdc.gov/niosh/nmam/>

Therefore, it has been suggested that protoporphyrin results be compared with previous results from the same individual. ZPP is the easiest to measure and interpret at typical occupational levels of lead exposure. FEP can be measured by fluorescence spectrofluorimetry.³ For practical reasons it is suggested that the testing for ZPP or FEP only be initiated once removal limits have been reached.

Hazards Associated with Inorganic Lead

Lead affects humans of all ages, but the effects of lead are considered most serious in young children. Lead uptake occurs as a result of ingestion or inhalation of inorganic lead particles. Not only are particulates in air (dust and fume) important sources of exposure in the workplace, but also from eating and smoking with contaminated hands due to poor personal hygiene.

The respiratory tract provides the most efficient route of absorption while gastrointestinal absorption of lead is less efficient. When inhaled, most inorganic forms of lead deposited in the alveolar regions appear to be almost completely absorbed, although it is possible that lead compounds of low solubility such as lead sulphide may accumulate to some extent in the lung. Absorption of inhaled lead is affected by various factors including personal characteristics, physical activity, particle size and solubility of the airborne lead. Gastrointestinal absorption of lead is relatively poor in adults. Little is known about comparative rates of gastrointestinal absorption of different forms of lead (SCOEL, 2002).

Colic is a known acute symptom of lead poisoning in children. EPA cited by ASTDR (2007) identified a LOAEL of approximately 60–100 µg/dL for children. This value apparently is based on a National Academy of Sciences (NAS, 1972) compilation of unpublished data from the patient groups originally discussed in Chisolm (1962, 1965) and Chisolm and Harrison (1956) in which other signs of acute lead poisoning, such as severe constipation, anorexia, and intermittent vomiting, occurred at ≥ 60 µg/dL (ASTDR, 2007).

Acute poisoning is uncommon today in occupational settings. More commonly, lead poisoning is a chronic disease by the gradual accumulation of a significant body burden. The effects of repeated exposure have been extensively investigated in animal models, mainly with the oral route of administration. Effects on the haemopoietic, renal, nervous and reproductive systems have been reported (ACGIH, 2001; SCOEL, 2002). Table 3 denotes that these health effects may occur at blood lead levels ≥ 60 µg/dL.

Where blood levels are greater than 40 µg/dL, health effects can possibly include anaemia, hypertension and kidney disease (refer to Table 3 (AOEC, 2007)). However, kidney disease is more likely in individuals exposed for more than 10 years. Damage to the sperm has been reported and long term exposure has also been reported to adversely affect the nervous system (ACGIH, 2001).

³ **Note:** Refer to Workcover NSW Laboratory Services Unit Handbook for specific information on sample collection and limit of detection.

Major Uses / Potential for Exposure (in Australia)

Lead is found at low concentrations in the earth's crust, predominantly as lead sulphide, but the widespread occurrence of lead in the environment is largely the result of anthropogenic activity. Significant sources of lead exposure occur for mining and smelting of lead. Around 3.2 million tonnes of lead are mined in the world each year. Geological deposits of lead are found all over the world, but countries with the largest mines are Australia, China and the USA (Table 1). The BHP Billiton Cannington mine is the world's single largest mine currently producing lead. For the financial year ending 30 June 2005, the mine produced over 280,000 tonnes of lead concentrate, along with over 52,000 tonnes of zinc concentrate. Xstrata Mt Isa Mines and Broken Hill are also typical lead producers in Australia. Smelters in Australia include those of Nyrstar at Port Pirie and Xstrata at Mt Isa. The Port Pirie smelter, located on the eastern shore of Spencer Gulf, South Australia, was built in 1889 for processing early Broken Hill lead concentrates. Since then it has been progressively upgraded and is now the largest primary lead smelter in the world. Currently, its blast furnace limits its capacity to approximately 245,000 tonnes per year, however, other parts of the facility have a capacity of approximately 270,000 tonnes. The current zinc and copper production facilities were commissioned in 1967 and 1984 respectively and the lead smelter in which gold and silver are largely recovered was rebuilt in 1998. Large quantities of lead, both as the metal and dioxide, are used in storage batteries. Lead is also used for cable covering, plumbing and ammunition. The metal is very effective as a sound absorber and as a radiation shield around x-ray equipment and nuclear reactors. The forms of lead produced and used in Australia include; metallic lead, lead acetate, lead carbonate, lead fluoroborate, lead naphthenate, lead stearate, lead nitrate, lead monoxide, lead dioxide and lead subacetate.

Table 1: World-wide Production of Lead Ore by Region⁴

	Mine production in 2000 (lead content in thousand tonnes).
Western Europe	242
Central and Eastern Europe	121
Africa	181
North America	607
Central and South America	446
China	560
Rest of Asia	135
Australia	650
Total	2942

Table 2: World-wide Production of Refined Lead Metal by Region⁴

	Production in 2000 (lead content in thousand tonnes).
Western Europe	1578
Central and Eastern Europe	309
Africa	135
North America	1705
Central and South America	478
China	1051
Rest of Asia	1017
Australia	261
Total	6532

⁴ Source: Lead Development Association International - <http://www.ldaint.org/default.htm>

Risk of Health Effects

Toxicity depends mainly on particle solubility and its size, since these determine how easily it is absorbed (Firth, 2007). The greatest hazard in the workplace has typically been inhaled lead, either as particulate (dust) or as lead fume but the contribution of ingestion can be significant due to smoking and eating where personal hygiene is poor. Inhaled dust and fume will also be swallowed following lung clearance by upper respiratory tract mechanisms. Soluble lead salts are very toxic if swallowed. The smaller the particle size the more rapid their absorption, hence the more acute and severe the toxic effect. Thermally generated fumes of the metal are more often involved in lead poisoning; on inhalation, fumes can pass easily through the lung alveolar wall directly into the blood stream. These fumes contain the easily soluble lead suboxide, common in the grey fume that occurs in and around lead smelters and brass foundries. For inorganic lead, absorption through the skin is negligible.

Blood lead levels are a good reflection of absorption of lead into the body (Table 3). The upper limit of blood lead in the general population is about 10µg/dL and most workers will be clinically lead poisoned at 80 µg/dL (Lundströrom *et al.*, 1997). Induced haematological changes such as increased erythrocyte protoporphyrin occur at blood lead levels as low as 35µg/dL. Lead in serum or plasma, considered to be more biologically active, rises steeply at blood levels above 40µg/dL. It is suggested that lead may affect critical organs above this value. There is neurobehavioral evidence of lead induced alterations in human behaviour and performance at PbB levels as low as 29 µg/dL (Lundströrom *et al.*, 1997).

Menke *et al.* (2006) identified that there may be a risk to the population and increased risk of mortality as low as 10 µg/dL from myocardial infarction and stroke. However the authors were unsure whether the adverse health effects of lead observed were associated with current or cumulative exposures. They also noted that because of declining lead levels in the decades before, it was unclear whether the observed increased risk in mortality was due to lead exposure at baseline or lead mobilization from the skeleton (Menke *et al.*, 2006).

The European Directive 67/548/EEC has assigned R-phrases as an indicator of health affects associated with a number of chemicals. For lead compounds, R-phrases that have been assigned and corresponding potential health effects are listed as follows:

- | | |
|---------------|---|
| R61 | May cause harm to the unborn child. |
| R20/22 | Harmful by inhalation and if swallowed. |
| R33 | Danger of cumulative effects. |
| R63 | Possible risk of impaired fertility. |
| R50/53 | Very toxic to aquatic organisms - may cause long term adverse effects in the aquatic environment. |

One of the major concerns with lead is that it interferes with biochemical process that the body uses to produce blood (Krebs Cycle). The inhibition of a chemical in the Krebs Cycle produces elevated levels of protoporphyrin in red blood cells (*Lauwerys et al.*, 2001). Therefore testing for free erythrocyte porphyrins (FEP) or zinc protoporphyrin (ZPP) will indicate whether the Krebs Cycle is being effected. These indicators are also important for body burden as the accumulation of protoporphyrin in erythrocytes results from the action of lead in the bone marrow (*Lauwerys et al.*, 2001).

Lead readily crosses the placenta and may exert adverse effects on the outcome of a pregnancy and the foetus (Skerfving, 2005). Lead poisoning has been associated with an increased risk of spontaneous abortion, pre-term delivery, stillbirth, and increased incidence of infant mortality (see Table 3). The World Health Organization (WHO, 2001), has recommended “that for the general population that efforts be made to ensure that at least 98% of an exposed population, including preschool children, have blood leads that do not exceed 10 µg /dL”. WHO have also recommended that median blood lead levels do not exceed 5.4 µg /dL. The authors of this position document believe that it is especially important for females of reproductive capacity to not exceed these values, due to potential health effects to an unborn foetus.

Table 3: Overview of health effects to lead-exposed adults at different blood lead levels⁵ (AOEC, 2007)

Blood Lead Level µg/dL (µmol/L)				
5 – 9 (0.24 – 0.43)	10 – 19 (0.48 – 0.92)	20 – 39 (0.97 – 1.88)	40 – 79 (1.93 – 3.81)	≥ 80 (≥ 3.86)
Possible adverse population effects suggested by epidemiological studies.	Possible spontaneous abortion.	Spontaneous abortion.	Spontaneous abortion.	Spontaneous abortion.
	Reduced newborn birth weight.	Reduced newborn birth weight.	Reduced newborn birth weight.	Reduced newborn birth weight.
	Possible blood pressure changes.	Possible blood pressure changes.	CNS effects.	CNS effects.
	Possible renal dysfunction.	Possible renal dysfunction.	Sperm effects → Lowered counts → Abnormal sperm	Sperm effects
		Possible non specific symptoms: → Headache → Fatigue → Sleep disturbance → Anorexia → Constipation → Diarrhoea → Arthralgia → Myalgia → Decreased libido → Mood swings → Personality changes	Subclinical peripheral neuropathy.	Peripheral neuropathy.
		Possible CNS effects, Memory and attention deficits.	Possible hypertension.	Hypertension.
			Possible anaemia.	Anaemia
			Possible renal damage.	Abdominal Colic.
			Possible gout.	Nephropathy.
				Gout.

⁵ Sourced from the Association of Occupational and Environmental Clinics (AOEC) - <http://www.aoec.org/principles.htm>

Lead itself can interact with proteins, including those involved in DNA repair. This latter mechanism may be responsible for the enhancement of genetic toxicity caused by other agents. These properties could result in mutation, cell proliferation and changes in gene expression, all of which would contribute to a carcinogenic response under conditions of sustained exposure. In February 2004, “the IARC Working Group reached the following overall evaluations: lead compounds are probably carcinogenic to humans (Group 2A) (IARC, 2004). With regard to kidney cancer IARC 2004 noted that “*Five of the six cohort studies reported findings for kidney cancer. In one study, there was a statistically significant two-fold excess of kidney cancer, based on comparison with an external reference population. All five studies were based on small numbers of deaths*”.

There are numerous studies to demonstrate that chronic exposure to lead results in increased body burden. According to O’Flaherty *et al* (1982), the average time required to reach pre-established blood lead levels in workers removed from exposure will increase with the workers previous exposures. In addition, the association between bone and blood lead levels in retired workers indicates a risk of lead being released from the skeleton (*Lauwerys et al.*, 2001).

For the prevention of chronic health effects of cumulative dose the available evidence suggest that tibia lead levels should not be allowed to exceed 15 µg lead/g bone mineral; this could also be achieved by maintaining the cumulative blood index below approximately 200 – 400 µg -years/dL (equivalent to an average blood lead level of 20 µg /dL for 10 – 20 years or of 10 µg /dL for 20 – 40 years (Shwartz & Hu, 2007).

In line with the method outlined in Hu *et al* (2007), good practice will ensure that the cumulative blood lead index be maintained below 200 – 400 µg-years / dL (equivalent to an average blood lead level of 20 µg/dL for 10 – 20 years or of 10 µg/dL for 20 – 40 years).

Available Controls

Containment, engineering controls and housekeeping are important controls. According to current requirements, where there is potential for PbB to be determined ≥ 30 µg/dL, there should be a system for managing and controlling exposures in accordance with the National Standard Control of Inorganic Lead at Work (NOHSC:1012). Workplaces considered “at risk” will be clean in / clean out which means that all laundering is carried out on site.

Designated facilities must be made available for personal hygiene including designated washing and showering facilities to cater for all employees and contractors. A rigorous cleaning process must be in place where there is daily cleaning of all amenities including canteens / meal rooms. Smoking must also be prohibited at the workplace.

An induction is required as well as ongoing awareness programmes specifically to highlight the health effects of lead and promote good hygiene practices. Supervisors / Line Managers must also be responsible for encouraging employees and contractors to maintain acceptable PbB. Where PbB exceed acceptable levels, then the Supervisor and employee or contractor, must investigate and follow-up on controls and work practices where required.

Where possible roadways and surfaces must be sealed and airborne dust must be minimised following the hierarchy of control preferably by enclosing lead process complemented with ventilation and or dust suppression.

Current Applicable Legislation and Standards

Australian Statutory requirements generally refer to the National Standard for the Control of Inorganic Lead at Work (NOHSC: 1012) (Table 4). The current ASCC national exposure standard is 0.15 mg/ m³ (TWA). According to this standard, a **lead-risk** job for a worker means work in which the blood lead level of the worker might reasonably be expected to rise or does rise, above 30 µg/dL. For medical removal the following applies:

- 2.41 µmol/L (50µg/dL) - for males and females not of reproductive capacity,
- 2.41 µmol/L (50µg/dL) - for males of reproductive capacity,
- 0.97 µmol/L (20µg/dL) - for females of reproductive capacity,
- 0.72 µmol/L (15µg/dL) - for females who are pregnant or breast feeding.

Table 4: Australian Statutory requirements for managing lead at work

State	Document	Year	Title
National	Standard	1994	National Standard for the Control of Inorganic Lead at Work [NOHSC:1012(1994)]
National	Code of Practice	1994	National Code of Practice for the Control and Safe Use of Inorganic Lead at Work [NOHSC:2015(1994)]
Commonwealth	Code of Practice	1999	Approved Code of Practice on the Control and Safe Use of Inorganic Lead in Commonwealth Employment 1999
Victoria	Regulation	2007	Occupational Health and Safety Regulations Part 4.4 Lead
Victoria	Code of Practice	2000	Code of Practice for Lead No 26
Queensland	Regulation	1997	Workplace Health and Safety Regulation 7.4
Queensland	Information	2005	Hazardous Materials - Lead
NSW	Regulation	2001	Occupational Health and Safety Regulation part 7.6
SA	Regulation	1995	Occupational Health, Safety and Welfare Regulations Div 4.3
WA	Regulation	1996	Occupational Safety and Health Regulations 1996 Subdivision 2 Lead
WA	Guideline	1997	Department of Industry and Resources Biological Monitoring Guideline
NT	Regulation	2006	Work Health (Occupational Health and Safety) Regulations Division 5
TAS	Regulation	1998	Workplace Health and Safety Regulations section 68

Table 5: Current international occupational exposure limits (OELs)⁶

Country	OEL TWA mg/m ³	Carcinogenicity Categories	Biological Exposure Limits	PbB µg /dL
Argentina	0.05	A3	BEI	30
Australia	0.15			50
Austria	0.1			
Bulgaria	0.05			
Canada				
Alberta	0.05	2A		
British Columbia	0.05			
Quebec	0.05			
Chile	0.12		Límites de Tolerancia Biológica	50
Denmark	0.05		BEV	20
Estonia	0.1			
France	0.1			
Germany			Biological tolerance values	40 (30)
Hungary	0.15, 0.05 (resp)			
Ireland	0.15		Biological limit value	70
Japan	0.1	2B		40 (Proto 80 µg /dL)
New Zealand	0.1			67 (54)
South Africa	0.1			
Spain				70
Sweden	0.1 (0.05 resp)			
Switzerland	0.1		VBT - Males and females > 45 yr Females < 45 yr	40 10
UK	0.15			
USA				
NIOSH REL	0.05			60
OSHA PEL	0.05			
ACGIH	0.05	A3	BEI	30

⁶ Sourced through the International Labour Organisation -
<http://www.ilo.org/public/english/protection/safework/cis/products/explim.htm#zaf>

There are a number of studies that have attempted to correlate blood lead with airborne lead levels, in an attempt to develop an in-air occupational exposure limit (OEL). There are inconsistencies in the literature when trying to correlate airborne lead with blood lead (LDAI, 2007). A study by Askin *et al* (1997) cited in LDAI 2007, demonstrated that there was a significant association between lead levels in blood and lead on the hand surface of workers in a lead processing facility. Even where airborne lead is adequately controlled, where there is poor personal hygiene and sub-optimal work practices, exposure by ingestion can be significant. Cherrie *et al* (2006) also carried out a comprehensive review of ingestion of hazardous substances at work. In this review it was noted that “*with the success of control measures to reduce inhalation and dermal exposure, the fraction of total body burden arising from the ingestion route may increase. This may be particularly true where the interventions are focused on modifying the source rather than changing the process of the work environment or in reducing the mass of material taken up through the skin*”. Therefore, blood lead should be used as the primary indicator of exposure and air monitoring considered complementary to evaluate the effectiveness of controls for airborne lead.

Considering the range of OELs for the countries reviewed (Table 5), it would appear reasonable that where lead in air is greater than 0.05 mg/m^3 or where a risk assessment indicates a need, a blood lead monitoring programme should be required. An occupational exposure limit of 0.1 mg/m^3 (TWA) measured as inhalable lead is also considered reasonable.

Based on the information provided by the AOEC (2007) as provided in table 3 and the WHO limit of $< 10 \text{ } \mu\text{g/dL}$, the aspiration should be to reduce PbB to $\leq 10 \text{ } \mu\text{g/dL}$. For males and females (of a non child bearing age), where the level is $\geq 20 \text{ } \mu\text{g/dL}$, controls including work practices, should be reassessed and when the level is $\geq 30 \text{ } \mu\text{g/dL}$ the worker should be transferred to a non lead risk job.

AIOH Recommendation

The AIOH is of the opinion that the National Standard for the Control of Inorganic Lead at Work (NOHSC:1012) does not offer an acceptable level of protection for “nearly all workers”, especially females of reproductive capacity.

Blood lead (PbB) should remain the primary indicator to assess exposure. The AIOH recommends that where there is potential for males and females (of reproductive age) to reach PbB of $\geq 20 \text{ } \mu\text{g/dL}$ and $\geq 10 \text{ } \mu\text{g/dL}$ respectively, there should be a system for managing and controlling exposures. The transfer level for PbB should be reduced to $30 \mu\text{g/dL}$ for males.

It is recommended that for females of reproductive age the transfer level for lead in blood be reduced to $\geq 10 \mu\text{g/dL}$.

The frequency of PbB monitoring should increase as PbB approaches the transfer level.

For **contractors** and **new workers**, a blood lead test is required and the result must be $\leq 20 \text{ } \mu\text{g/dL}$ and $\leq 10 \text{ } \mu\text{g/dL}$ for males / females and females (of reproductive capacity), **respectively**, before they are permitted to work in a lead-risk job.

In addition, females of reproductive capacity should be informed about the reproductive hazards where PbB may exceed 10 µg/dL. It is highly recommended that in order to give maximum protection to the foetus, women who are planning a pregnancy should endeavour to limit lead to a level **well below** 10 µg/dL for a period of at least a year prior to pregnancy.

To reduce potential exposure to airborne lead, an exposure standard of 0.1 mg/m³ (TWA) is recommended, and where lead in air is greater than 0.05 mg/m³ or where a risk assessment indicates a need, a PbB monitoring programme is required. This is in line with a number of overseas organisations.

The AIOH acknowledge that currently, assigning a transfer level of 30µg/dL (for males) will not be complied with in a number of industries. Therefore the AIOH recommends that an interim level of 40 µg/dL be considered until the end of 2009. At the commencement of 2010 a transfer level of 30 µg/dL is therefore highly recommended.

The AIOH also recognizes that cumulative dose is an important measure and one way of expressing cumulative dose is the cumulative blood lead index (CBLI), or PbB, multiplied by years as described by Shwartz and Hu (2007).

The AIOH acknowledges that for longer term employees it may be difficult to meet the above. However, for new workers good practice means maintaining blood leads below 10 µg/dL.

The AIOH considers that the abovementioned control measures will ensure that the body burden of lead is kept as low as reasonably practicable.

The information gaps for health aspects of lead are now well documented. The AIOH recommends that ZPP or FEP be used to monitor males/females and females of reproductive capacity that have exceeded PbB of 30 µg/dL and that protoporphyrin results be compared with previous results from the same individual.

FEP and ZPP are biochemical indicators of exposure. They indicate that lead is interfering with the biosynthesis of heme. With respect to FEP and ZPP, at blood lead levels, at and above 30 µg/dL, they provide an indication of whether the elevated blood lead is due to short-term or longer-term exposures.

FEP or ZPP can be used to determine whether longer term exposures are increasing, which will provide impetus for additional controls.

The AIOH strongly recommends that any health surveillance, including biological monitoring, is carried out under the direction of an appropriately trained Occupational Physician.

The AIOH also warns against accidental specimen contamination.

In addition the AIOH highly recommends that appropriate blood lead collection techniques be followed. The AIOH also, strongly recommends, the use of a NATA accredited laboratory or equivalent be selected to perform analysis for both airborne lead and blood lead.

In light of the collective epidemiological evidence the AIOH considers that there is no fine dividing line between safe and unsafe levels of exposure. Therefore, ongoing efforts are required to ensure that exposures are as low as reasonably practicable (ALARP).

Summary of AIOH recommended blood lead transfer levels:

- 1.94 µmol/L (40µg/dL) - for males and females not of reproductive capacity **to end 2009**,
- 1.45 µmol/L (30µg/dL) - for males and females not of reproductive capacity **from start 2010**,
- 0.48 µmol/L (10µg/dL) - for females of reproductive capacity **from start 2009**.
- Immediate transfer from lead risk job once a female is pregnant.
- Pre-employment blood lead for contractors and new starters – males and females (non reproductive) and females (reproductive) ≤ 20µg/dL and ≤ 10µg/dL respectively. These results should be obtained prior to them commencing work.

References and Sources of Additional Information

ACGIH (2001). Documentation of TLVs and BEIs for Lead and Inorganic Compounds. *American Conference of Governmental Industrial Hygienists*, Cincinnati, Ohio (www.acgih.org).

AOEC (2007). Medical Management Guidelines for Lead-Exposed Adults Revised 04/24/2007 Sourced from the Association of Occupational and Environmental Clinics (AOEC) - <http://www.aoec.org/principles.htm>

AS 3640-2004: Workplace atmospheres - Method for sampling and gravimetric determination of inhalable dust. Standards Australia, Sydney.

Agency for Toxic Substances and Disease Registry ((ASTDR) (August 2007). US Department of Health and Human Services Public Health Service. Toxicological Profile for Lead.

Cherrie, J, Semple, S, Christopher, Y, Saleem, A, Hughson, G & Phillips, A (2006). How Important is Inadvertent Ingestion of Hazardous Substances at Work? *Annals of Occupational Hygiene*, 50(7): 693-704;
(<http://annhyg.oxfordjournals.org/cgi/content/full/50/7/693>)

Firth, IC (2007). Metals in the Workplace. In *Principles of Occupational Health & Hygiene: An Introduction*, Ed by C Tillman. Allen & Unwin, Crows Nest, NSW, Australia.

Hu, H, Shih, R, Rothenberg, S & Schwartz, BS (2007). The Epidemiology of Lead Toxicity in Adults: Measuring Dose and Consideration of Other Methodological Issues. *Health Perspectives, Mini-monograph 115(3)*; 455-462.
<http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1849918>, accessed 21/09/07.

International Agency for Research on Cancer (IARC), Monographs on the Evaluation of Carcinogenic Risks to Humans. Inorganic and organic lead compounds. Vol 87 10 – 17 February 2004. <http://www-cie.iarc.fr/htdocs/announcements/vol87.htm>

International Labour Organisation -
<http://www.ilo.org/public/english/protection/safework/cis/products/explim.htm#zaf>

Kosnett, MJ & Wedeen, RP (2007). Recommendations for Medical Management of Adult Lead Exposure. Mini-monograph. *Environmental Health Perspectives*, 115 (3)

Lauwerys, RR & Hoet, P (2001). Industrial Chemical Exposure Guidelines for Biological Monitoring (Third Edition).

Lead Development Association International - <http://www.ldaint.org/default.htm>

Lead Development Association International (July 2007), Voluntary Risk Assessment Report on Lead and Some Lead Compounds. Human Health Section, Interim Revised Draft prepared by the ILZRO and EBRC Consulting under contract to the LDAI Lead Risk Assessment Working Group. **Unpublished Report.**

Lundström, N-G, Nordberg, G, Englyst, V, Gerhardsson, L, Hagmar, L, Jin, T, Rylander, L, & Wall, S (1997). Cumulative lead exposure in relation to mortality in a cohort of primary smelter workers. *Scand, J, Work Environ, Health*, 23; 24-30.

Medical Management Guidelines for Lead-Exposed Adults Revised 04/24/2007. Website entered 02/08/2007 <http://www.atsdr.cdc.gov/HEC/natorg/aoec.html>

Menke, A, Munter, P, Batuman, PV, Silbergeld, E & Guallar, E (2006). Blood lead below 10 ug/dL and Mortality among US Adults. *Journal of the American Heart Foundation. Circulation* 114; 1388 – 1394; originally published online Sep 18, 2006.

NAS (1972). Lead: Airborne lead in perspective. Washington, DC: National Academy of Sciences, 71177 281-313.

National Occupational Health and Safety Commission (NOHSC 1994) – Control of Lead at Work. National Standard for the Control of Inorganic Lead at Work (NOHSC:1012(1994)).

O’Flaherty, EJ, Hammond, PB & Lerner, SI (1982). Dependence of apparent blood lead half-life on the length of previous lead exposure in humans. *Fundam Appl Toxicology*, 2, 49.

OSHA - Safety and Health Topics – Lead, at <http://www.osha.gov/SLTC/lead/>, accessed 3/9/2007.

Pickford, G & Davies, B (2007). Aerosols. In Principles of Occupational Health & Hygiene: An Introduction, Ed by C Tillman. Allen & Unwin, Crows Nest, NSW, Australia.

Schwartz, BS & Hu, H (2007). Adult Lead Exposure: Time for Change. *Environmental Health Perspectives, Mini-monograph* 115(3); 451-454.
<http://www.ehponline.org/docs/2006/9782/abstract.html>, accessed 21/09/2007.

Skerving, S (2005). Criteria Document for Swedish Occupational Standards Inorganic Lead – an update 1991–2004. The Swedish Group for Occupational Standards. Department of Occupational and Environmental Medicine. Lund Sweden.
<https://gupea.ub.gu.se/dspace/handle/2077/4356>

SCOEL (2002). Summary of Scientific Committee for Occupational Exposure Limits (SCOEL) Recommendations for Occupational Exposure Limits.

The European Directive 67/548/EEC, European Chemicals Bureau
<http://ecb.jrc.it/classification-labelling/search-classlab/>

Wooller, KK (2003). Occupational Medicine Handbook (Eleventh Edition), Information for Workcover Authority of NSW Authorised Medical Practitioners.

Workcover NSW 2003 – 5th Ed. Laboratory Services Unit Handbook

World Health Organisation (2001). Air Quality Guidelines – Second Edition. WHO Regional Office for Europe, Copenhagen, Denmark 2001.