

# Water soluble lead(2+) salts: Environment tier II assessment

30 June 2020

**CAS Registry Number: 10099-74-8, 7783-46-2, 7758-95-4, 10031-22-8, 10101-63-0, 13814-96-5, 17570-76-2, 811-54-1, 301-04-2, 6080-56-4, 1335-32-6, 815-84-9, 6107-83-1, 512-26-5, 14450-60-3**



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## Preface

This assessment was carried out by staff of the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) using the Inventory Multi-tiered Assessment and Prioritisation (IMAP) framework.

The IMAP framework addresses the human health and environmental impacts of previously unassessed industrial chemicals listed on the Australian Inventory of Chemical Substances (the Inventory).

The framework was developed with significant input from stakeholders and provides a more rapid, flexible and transparent approach for the assessment of chemicals listed on the Inventory.

Stage One of the implementation of this framework, which lasted four years from 1 July 2012, examined 3000 chemicals meeting characteristics identified by stakeholders as needing priority assessment. This included chemicals for which NICNAS already held exposure information, chemicals identified as a concern or for which regulatory action had been taken overseas, and chemicals detected in international studies analysing chemicals present in babies' umbilical cord blood.

Stage Two of IMAP began in July 2016. We are continuing to assess chemicals on the Inventory, including chemicals identified as a concern for which action has been taken overseas and chemicals that can be rapidly identified and assessed by using Stage One information. We are also continuing to publish information for chemicals on the Inventory that pose a low risk to human health or the environment or both. This work provides efficiencies and enables us to identify higher risk chemicals requiring assessment.

The IMAP framework is a science and risk-based model designed to align the assessment effort with the human health and environmental impacts of chemicals. It has three tiers of assessment, with the assessment effort increasing with each tier. The Tier I assessment is a high throughput approach using tabulated electronic data. The Tier II assessment is an evaluation of risk on a substance-by-substance or chemical category-by-category basis. Tier III assessments are conducted to address specific concerns that could not be resolved during the Tier II assessment.

These assessments are carried out by staff employed by the Australian Government Department of Health and the Australian Government Department of the Environment and Energy. The human health and environment risk assessments are conducted and published separately, using information available at the time, and may be undertaken at different tiers.

This chemical or group of chemicals are being assessed at Tier II because the Tier I assessment indicated that it needed further investigation.

For more detail on this program please visit: [www.nicnas.gov.au](http://www.nicnas.gov.au).

## Disclaimer

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### Acronyms & Abbreviations

## Grouping Rationale

This Tier II assessment considers the environmental risks associated with industrial uses of fifteen water soluble lead(2+) salts.

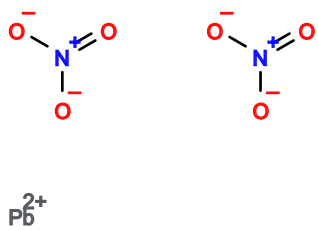
The chemicals in this group have uses in a variety of specialised applications including mineral processing, chemical manufacture, surface treatments, professional reprography, staining in electron microscopy, and hair dyes, and some have historical uses in lead paints (Pandithage, 2013; UNEP, 2010). The quantities of lead used in these applications are expected to be significantly less than those for lead compounds used for other industrial applications such as batteries, which account for 80% of lead consumption (UNEP, 2010).

The chemicals in this group are chemically related in that they all contain lead in the +2 oxidation state and a partner anion that is not considered to contribute significantly to their toxicity. Based on the identity of the anion, the chemicals can be separated further into two subgroups: lead salts of strong acids and lead salts of short-chain carboxylic acids. Chemicals within a subgroup have commonalities which are linked by the fate and behaviour of the anion in the environment.

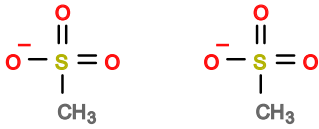
The risk assessment of these compounds has been carried out as a group because all fifteen lead salts are soluble to very soluble in water (25 mg/L to 456 000 mg/L) and they can all therefore potentially release lead(2+) ions into water. This provides a common source of toxicity for each of these substances. Based on the above considerations, the principal environmental concerns arising from industrial uses of all fifteen chemicals are considered to be sufficiently similar for them to be assessed as a single group.

## Chemical Identity

### Lead Salts of Strong Acids

CAS RN	10099-74-8
Chemical Name	Nitric acid, lead(2+) salt
Synonyms	lead nitrate lead dinitrate lead(II) nitrate lead(2+) nitrate
Structural Formula	 <p>The structural formula shows two nitrate ions (NO<sub>3</sub><sup>-</sup>) and a lead ion (Pb<sup>2+</sup>). Each nitrate ion consists of a central nitrogen atom (blue) bonded to three oxygen atoms (red). One oxygen atom is double-bonded to the nitrogen, and the other two are single-bonded, each carrying a negative charge. The lead ion is represented as Pb<sup>2+</sup>.</p>
Molecular Formula	Pb(NO <sub>3</sub> ) <sub>2</sub>
Molecular Weight (g/mol)	331.21

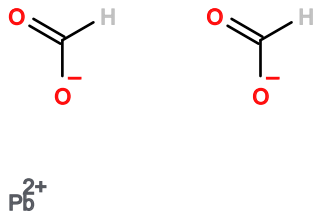
CAS RN	17570-76-2
Chemical Name	Methanesulfonic acid, lead(2+) salt
Synonyms	lead methanesulfonate

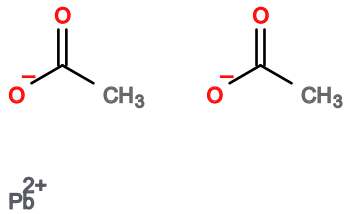
Structural Formula	 <p style="text-align: center;"><math>\text{Pb}^{2+}</math></p>
Molecular Formula	$\text{Pb}(\text{CH}_3\text{SO}_3)_2$
Molecular Weight (g/mol)	397.40
CAS RN	7783-46-2
Chemical Name	Lead fluoride ( $\text{PbF}_2$ )
Synonyms	lead fluoride
Molecular Formula	$\text{PbF}_2$
Molecular Weight (g/mol)	245.20
CAS RN	7758-95-4
Chemical Name	Lead chloride ( $\text{PbCl}_2$ )
Synonyms	lead chloride
Molecular Formula	$\text{PbCl}_2$

Molecular Weight (g/mol)	278.11
CAS RN	10031-22-8
Chemical Name	Lead bromide (PbBr <sub>2</sub> )
Synonyms	lead bromide
Molecular Formula	PbBr <sub>2</sub>
Molecular Weight (g/mol)	367.01
CAS RN	10101-63-0
Chemical Name	Lead iodide (PbI <sub>2</sub> )
Synonyms	lead iodide
Molecular Formula	PbI <sub>2</sub>
Molecular Weight (g/mol)	461.01
CAS RN	13814-96-5
Chemical Name	Borate(1-), tetrafluoro-, lead(2+) (2:1)

Synonyms	lead tetrafluoroborate lead fluoroborate lead bis(tetrafluoroborate)
Molecular Formula	Pb(BF <sub>4</sub> ) <sub>2</sub>
Molecular Weight (g/mol)	380.81

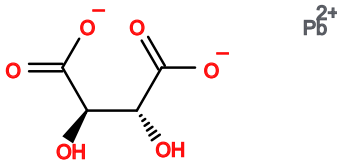
## Lead Salts of Short-chain Carboxylic Acids

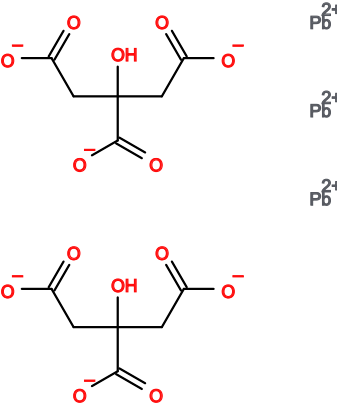
CAS RN	811-54-1
Chemical Name	Formic acid, lead(2+) salt
Synonyms	lead formate lead diformate lead(2+) diformate
Structural Formula	
Molecular Formula	Pb(HCO <sub>2</sub> ) <sub>2</sub>
Molecular Weight (g/mol)	297.23

SMILES	[Pb++].C([H])(=O)[O-].C([H])(=O)[O-]
CAS RN	301-04-2
Chemical Name	Acetic acid, lead(2+) salt
Synonyms	lead acetate lead diacetate lead(2+) diacetate
Structural Formula	
Molecular Formula	Pb(CH <sub>3</sub> CO <sub>2</sub> ) <sub>2</sub>
Molecular Weight (g/mol)	325.29
SMILES	[Pb++].CC(=O)[O-].CC(=O)[O-]
CAS RN	6080-56-4
Chemical Name	Acetic acid, lead(2+) salt, trihydrate
Synonyms	lead acetate trihydrate lead diacetate trihydrate lead(2+) diacetate trihydrate

Molecular Formula	$\text{Pb}(\text{CH}_3\text{CO}_2)_2 \cdot 3\text{H}_2\text{O}$
Molecular Weight (g/mol)	379.33
CAS RN	1335-32-6
Chemical Name	Lead, bis(acetato-O)tetrahydroxytri-
Synonyms	lead subacetate basic lead acetate
Structural Formula	<p>The structural formula shows a central lead(II) ion (<math>\text{Pb}^{2+}</math>) coordinated to two acetate groups and three hydroxide groups. Each acetate group is represented as a central carbon atom double-bonded to an oxygen atom and single-bonded to a methyl group (<math>\text{CH}_3</math>) and a negatively charged oxygen atom. The hydroxide groups are represented as a hydrogen atom single-bonded to a negatively charged oxygen atom. The lead ion is coordinated to the negatively charged oxygen atoms of the acetate groups and the oxygen atoms of the hydroxide groups.</p>
Molecular Formula	$\text{Pb}(\text{CH}_3\text{CO}_2)_2 \cdot 2\text{Pb}(\text{OH})_2$
Molecular Weight (g/mol)	807.72
SMILES	<chem>[Pb++].[Pb++].[Pb++].CC(=O)[O-].CC(=O)[O-].[OH-].[OH-].[OH-].[OH-]</chem>
CAS RN	815-84-9
Chemical Name	Butanedioic acid, 2,3-dihydroxy- [R-(R*,R*)]-, lead(2+) salt (1:1)



Synonyms	lead tartrate
Structural Formula	
Molecular Formula	Pb[CO <sub>2</sub> C(OH)C(OH)CO <sub>2</sub> ]
Molecular Weight (g/mol)	355.27
SMILES	[Pb++].[O-]C(=O)[C@]([H])(O)[C@@]([H])(O)C([O-])=O

CAS RN	512-26-5
Chemical Name	1,2,3-Propanetricarboxylic acid, 2-hydroxy-, lead(2+) salt (2:3)
Synonyms	lead citrate trilead dicitrate
Structural Formula	

Molecular Formula	$\text{Pb}_3(\text{C}_6\text{H}_5\text{O}_7)_2$
Molecular Weight (g/mol)	999.80
SMILES	<chem>[Pb++].[Pb++].[Pb++].C(C(=O)[O-])C(O)(CC(=O)[O-])C(=O)[O-].C(C(=O)[O-])C(O)(CC(=O)[O-])C(=O)[O-]</chem>
CAS RN	14450-60-3
Chemical Name	1,2,3-Propanetricarboxylic acid, 2-hydroxy-, lead salt
Synonyms	lead citrate
CAS RN	6107-83-1
Chemical Name	1,2,3-Propanetricarboxylic acid, 2-hydroxy-, lead(2+) salt (2:3), trihydrate
Synonyms	lead citrate trihydrate trilead dicitrate trihydrate
Molecular Formula	$\text{Pb}_3(\text{C}_6\text{H}_5\text{O}_7)_2 \cdot 3\text{H}_2\text{O}$
Molecular Weight (g/mol)	1053.85

## Physical and Chemical Properties

All of the lead salts in this group are expected to be solids under ambient conditions with the exception of lead tetrafluoroborate (CAS RN 13814-96-5) (IARC, 2006). Lead tetrafluoroborate is available commercially as a concentrated solution of the salt in water and this is the only form in which it is stable (NLM, 2010).

Measured water solubility values for most of the salts in this group were retrieved from Weast (Weast R.C. (Ed.), 1976). The lower limit for the water solubility of lead methanesulfonate presented below was obtained from the supporting document prepared for the identification of this chemical as a Substance of Very High Concern (SVHC) by the European Chemicals Agency (ECHA, 2012):

Chemical	CAS RN	Water Solubility (mg/L)
lead nitrate	10099-74-8	376 500 (0°C)
lead methanesulfonate	17570-76-2	>200 000
lead fluoride	7783-46-2	640 (20°C)
lead chloride	7758-95-4	9900 (20°C)
lead bromide	10031-22-8	4500 (0°C)
lead iodide	10101-63-0	440 (0°C)
lead formate	811-54-1	16 000 (15°C)
lead acetate	301-04-2	443 000 (20°C)
lead acetate trihydrate	6080-56-4	456 100 (15°C)
lead tartrate	815-84-9	25 (20°C)
lead citrate trihydrate	6107-83-1	soluble (no value given)
lead citrate	512-26-5	not available
lead citrate	14450-60-3	not available

Lead subacetate (CAS RN 1335-32-6) is very soluble in water. The reported water solubility for this salt indicates that 250 grams will dissolve in 1000 grams of water at 25°C (IARC, 2006).

## Import, Manufacture and Use

### Australia

With the exception of lead nitrate, no specific Australian use, import, or manufacturing information has been identified for chemicals in this group. Lead nitrate is reported to be used in mineral processing as a flotation agent with an annual introduction volume in the range 1000 to 9999 tonnes (NICNAS, 2006).

Lead acetates are used in hair dyes that are marketed for use in Australia (NICNAS, 2015a; 2019). NICNAS has recommended that lead acetate should not be allowed for use in hair dyes in Australia following a recent re-assessment of the risks to human health from this use of lead acetate (NICNAS, 2019).

### International

Lead acetates were until recently approved for use in the United States as colour additives in progressive hair dye products (NICNAS, 2015a; 2019; US FDA, 2014). In the European Union and Canada, lead compounds have been prohibited from use in cosmetic products such as hair dyes (European Commission, 2009; Health Canada, 2014). Based on available information, the remaining lead salts (except lead nitrate) in this group are only used in laboratory settings or for specialised industrial applications, including electroplating.

A major use of lead nitrate is in mineral processing. For example, it is used as a leach accelerant to increase the quantity of gold recovered from gold ores (Marsden and House, 2006).

## Environmental Regulatory Status

### Australia

Lead and lead compounds are subject to reporting under the Australian National Pollutant Inventory (NPI). Under the NPI, emissions of lead and lead compounds are required to be reported annually by facilities that use or emit more than 10 tonnes of lead or lead compounds, burn more than 2000 tonnes of fuel, consume more than 60 000 megawatt hours of electricity (excluding lighting and motive purposes), or have an electricity rating of 20 megawatts during a reporting year (Australian Government Department of the Environment, 2014). Emissions may be intentional, accidental or incidental releases arising through industrial processes. Additionally, emissions of lead and lead compounds from diffuse sources, such as lawn mowers and wood heaters, are also periodically estimated by state environment authorities. Diffuse emissions data are updated much less frequently than facility data (Australian Government Department of the Environment, 2013).

The *Uniform Paint Standard of the Poisons Standard 2013* (Cwlth) (the Poisons Standard) restricts lead and lead compounds to a maximum of 0.1% of the non-volatile content of all paints manufactured and sold in Australia (measured as elemental lead).

The import of cosmetic products containing more than 250 milligrams per kilogram (mg/kg) (0.025% w/w) of lead as lead or lead compounds is prohibited under the *Customs (Prohibited Imports) Regulations 1956* (Cwlth). However, lead acetate compounds for use in hair products are exempt from this prohibition (Commonwealth of Australia, 1956).

In Australia, high reliability default guideline values for lead in freshwater and marine water have been determined (ANZECC, 2000a). To protect 95% of species in a *slightly-moderately disturbed* ecosystem, the guideline values are 3.4 and 4.4 micrograms of lead per litre ( $\mu\text{g Pb/L}$ ) for freshwater and marine water, respectively. For irrigated soil, a cumulative contaminant loading limit (CCL) guideline value has been set at 260 kilograms of lead per hectare ( $\text{kg Pb/ha}$ ) (ANZECC, 2000a). Nationally, an upper limit on lead contamination in biosolids has been recommended (300 mg Pb/kg dry weight) (NRMMC, 2004).

## United Nations

The chemicals in this group are not currently identified as Persistent Organic Pollutants (UNEP, 2001), ozone depleting substances (UNEP, 1987), or hazardous substances for the purpose of international trade (UNEP and FAO, 1998).

The United Nations Environment Programme (UNEP), in partnership with the World Health Organization (WHO), has established the Global Alliance to Eliminate Lead Paint. The alliance primarily supports actions in developing nations to reduce and phase-out lead use in paints (UNEP, 2011).

## OECD

Lead nitrate is listed as an OECD High Production Volume (HPV) chemical (OECD, 2009). The chemical is produced at a level greater than 1000 tonnes per year in at least one member country of the OECD.

The chemicals in this group have not been sponsored for assessment under the Cooperative Chemicals Assessment Programme (CoCAP) (OECD, 2013).

## Canada

The chemicals in this group are not listed under Schedule 1 (the Toxic Substances List) of the *Canadian Environmental Protection Act 1999* (CEPA 1999) (Government of Canada, 2016).

Some of the chemicals in this group (e.g., lead nitrate and lead acetate) are listed on the Canadian Domestic Substances List (DSL), and all were categorised as Persistent (P), not Bioaccumulative (Not B) and Inherently Toxic to the Environment (IT<sub>E</sub>) during the Categorisation of the DSL (Environment Canada, 2013).

Lead in most paint products available to consumers in Canada is limited to 90 mg/kg (0.009% w/w) of the non-volatile content under the *Surface Coating Materials Regulations* of the *Canada Consumer Product Safety Act 2010*. Exempted products which contain more than 90 mg/kg lead must be appropriately labelled (Government of Canada, 2005).

The use of lead compounds in cosmetic products is prohibited in Canada (Health Canada, 2014).

## European Union

The majority of the chemicals in this group (13 substances) have been pre-registered for use in the European Union under the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) legislation (ECHA, 2015). Nine substances have undergone the full registration process (ECHA, 2017).

Four chemicals in this group (lead nitrate, lead tetrafluoroborate, lead methanesulfonate and lead acetate) have been identified as SVHCs under the REACH legislation due to their reproductive toxicity. Of the four chemicals listed as SVHCs, two chemicals (lead methanesulfonate and lead acetate) are currently listed on the Candidate List for Eventual Inclusion in Annex XIV to REACH (ECHA, 2013b). Once included in Annex XIV to REACH (the Authorisation List), use of the chemical may be severely restricted.

## United States of America

Selected industries in the United States of America (USA), including most mining, utilities and manufacturing facilities, must report emissions of lead and lead compounds to the United States Environmental Protection Agency (US EPA) if the facility manufactures or processes more than 25 000 pounds (approximately 11 tonnes) of lead compounds per annum. Reporting is also required if the facility otherwise uses more than 10 000 pounds (approximately 4.5 tonnes) in a reporting year (US EPA, 2012; 2014a; 2014b).

Most paint products containing lead, as well as toys and furniture painted using such products, are prohibited in the USA if the lead content exceeds 0.009% w/w of the non-volatile paint content under the *Consumer Product Safety Improvement Act 2008*. Exempted products that contain more than 0.009% w/w lead must be appropriately labelled (United States Government, 2008).

The United States Food & Drug Administration (US FDA) terminated the listing of lead acetate for use in cosmetics intended for colouring hair on the scalp effective from 3 December 2018 (US FDA, 2018).

Most of the chemicals in this group (13 substances) are listed on the inventory of chemicals manufactured or processed in the USA, as published under the *Toxic Substances Control Act 1976* (TSCA) (US EPA, 2017).

## Environmental Exposure

Since the 1970s, anthropogenic inputs of lead into the environment have decreased following the phase-out of leaded petrol and the introduction of emission controls (UNEP, 2010). In Australia, a phase out of the use of lead based additives in petrol for on-road applications was completed in 2002 (NICNAS, 2015b). Furthermore, a National Lead Abatement program was established in the 1990s to reduce the environmental and health effects of lead in Australia (UNEP, 2005). Currently, in OECD countries, batteries account for 80% of lead consumption and lead compounds account for 8% (UNEP, 2010). The chemicals considered in this assessment constitute a small percentage of the latter group.

With the exception of the lead chemicals used in hair dyes, all chemicals in this assessment have limited potential for release to the environment. It is assumed that these salts will be a) retained within the manufactured article, b) consumed and/or used under controlled conditions and/or c) used in small volumes in accordance with appropriate disposal procedures.

The use of lead acetates in progressive hair dyes is expected to constitute a very small proportion of the total amount of lead introduced into the environment from anthropogenic sources (Cohen and Roe, 1991). Nevertheless, following the use of lead-containing hair dyes, these chemicals can be released into wastewater. This emission pathway will be the focus of this assessment given that these lead compounds are very soluble in water and can readily release lead(2+) ions.

Up to 96% of the total volume of lead entering a typical sewage treatment plant (STP) may be removed from the wastewater by adsorption to sludge (Lassen, et al., 2004) which may be applied to land as biosolids (stabilised sewage sludge). Therefore, emissions of lead(2+) to both environmental surface waters and soils are considered as part of this assessment.

## Environmental Fate

### Dissolution, Speciation and Partitioning

The behaviour of the lead(2+) ion is strongly dependent on the chemistry of the environmental compartment into which it is released.

The lead chemicals in this group are salts of either strong acids or weak carboxylic acids. Dissolution of the lead salts of strong acids results in at least partial dissociation of the anion (e.g. X<sup>-</sup>) and lead(2+) cation into the respective hydrated ions in aqueous solution. For the salts of the weakly acidic carboxylic acids, dissolution in water can result in hydrolysis of the anion. The extent to which this reaction occurs is dependent on the properties of the acid and the pH of the local environment. At neutral pH, mono-carboxylic acids are predominantly in the conjugate base (anionic) form.

For lead(2+) ions, coordinated water is only weakly acidic and the predominant form of the dissolved metal ion in pure water at neutral pH is the simple hydrated lead(2+) di-cation (Basolo and Pearson, 1967; Mauchauffee, et al., 2008). However, in environmental waters, lead(2+) ions are expected to undergo a range of additional reactions and they can therefore exist as a variety of different chemical species. The speciation chemistry of lead(2+) ions in environmental waters is complex and strongly dependent on water chemistry, especially pH and the presence of complexing anions. For example, at pH levels lower than 7, the simple hydrated lead(2+) di-cation is the dominant species of ionic lead (ANZECC, 2000b). However, at pH levels greater than 7, the speciation of ionic lead is dominated by the formation of carbonate complexes, such as PbCO<sub>3</sub> (US EPA, 1999).

In addition to complexation by simple inorganic anions, lead(2+) is complexed by organic matter in environmental waters. These complexes are of great significance for the environmental fate of lead(2+) because they account for the majority of dissolved lead in natural freshwater at pH values in the range 5 to 9 (ANZECC, 2000b). Further, the partitioning of lead(2+) from the water

phase onto clay particles, particulate humic substances, and iron, aluminium and manganese (oxy)hydroxides have all been identified as important mechanisms controlling the concentration of lead in natural waters. In sediments, the speciation of lead will be dominated by complexation by humic substances and the formation of relatively insoluble lead sulfides (ANZECC, 2000c).

The partitioning behaviour of lead in soil has a complex dependence on soil properties, but is mainly determined by cation exchange capacity (CEC), amorphous iron and aluminium oxides, pH and concentration of organic carbon (Bradham, et al., 2006; Dayton, et al., 2006). A detailed review of measured partition coefficients for sorption from water onto soil ( $K_D$  values) conducted by the US EPA identified values for lead(2+) in the range of 150 L/kg to 44 580 L/kg. The adsorption of lead on soil generally increases with increasing soil pH (US EPA, 1999). Lead is typically considered relatively immobile in soil (UNEP, 2010).

## Biotransformation

The halide ion components of the salts in this group are naturally occurring species in the environment. Background concentrations of these species are unlikely to be perturbed by the use of the lead halide salts in this assessment. The methanesulfonate anion will be rapidly degraded into sulfate and carbon dioxide by natural process as it is a component of the biogeochemical sulfur cycle (Baker, et al., 1991). For example, methanesulfonic acid is readily biodegradable in aquatic systems with 90% degraded after 14 days (ECHA, 2013a). The tetrafluoroborate anion ( $BF_4^-$ ) hydrolyses in water in a stepwise manner to give hydroxyfluoroborates, then boric acid (Ullmann's Encyclopedia of Industrial Chemicals, 2014). These degradation products are naturally ubiquitous in the environment.

The carboxylic acid components of the chemicals in this group are naturally occurring organic acids that are readily biodegradable in the environment. For example, citric acid (CAS RN 77-92-9) has been found to undergo 77% degradation in 14 days in a study conducted in accordance with OECD Test Guideline (TG) 301C. Similarly, tartaric acid (CAS RN 87-69-4) has been found to undergo 85% degradation in 28 days in a study conducted in accordance with OECD TG 306 (LMC, 2013).

## Bioaccumulation

Chemicals in this group will release lead(2+) ions, which bioaccumulate in most organisms.

The lead(2+) ions released from these chemicals may pose a bioaccumulation hazard depending on the bioavailability of the metal ion, which will be controlled by its speciation. Conventional measures of bioaccumulation as applied to organic chemicals are not appropriate for metal ions. These measures do not consider the potential for metals to accumulate in specific tissues, the physiological mechanisms available to organisms to regulate internal metal concentrations, and the influence of environmental factors (US EPA, 2007). Nevertheless, lead and lead compounds are globally acknowledged to pose a significant bioaccumulation concern (UNEP, 2010; 2014).

The carboxylic acid components of the chemicals in this group are not expected to pose a bioaccumulation hazard as they are naturally occurring, ubiquitous organic acids that are water soluble and readily biodegradable (LMC, 2013).

## Transport

The chemicals in this group and their ionic components have a low potential for long-range transport.

The lead(2+) salts in this group are ionic solids that do not partition to the atmospheric compartment, where long-range transport typically occurs. The ionic lead components of these salts may have some limited mobility in water due to complexation by dissolved organic matter, but lead released into water and onto soil will eventually become bound to sediment or soil particles (UNEP, 2010).

## Predicted Environmental Concentration (PEC)

A PEC was not calculated for the chemicals or their ionic components addressed under this assessment.

Emissions of all chemicals in this group from industrial uses are expected to be minor relative to total environmental lead loads. Furthermore, uses will occur under controlled conditions with appropriate waste management and disposal whereby wastes contaminated with lead are expected to be disposed of safely.

Release of lead(2+) to wastewater can occur from the use of lead acetates in progressive hair dyes in domestic situations. However, the quantities of lead released from this source are unlikely to be significant compared with other sources in households. The main sources of lead in household wastewater are from the laundry and bathroom where lead-containing dirt and dust are the suspected inputs (Tjadraatmadja and Diaper, 2006). While there are limited data regarding the emissions of lead from infrastructure in Australia, data from the UK indicate that infrastructure (e.g. tap fittings, lead-soldered pipes) will be a major source of lead emissions to domestic wastewater (Tjadraatmadja and Diaper, 2006).

Hair dye products which are assumed to contain up to 0.6% w/v lead (as lead acetate) are currently available in Australia (NICNAS, 2019). Use of hair dye products containing lead at this concentration is expected to contribute much less than one tonne of lead to the Australian environment per annum. This calculation is supported by a study carried out in 1981, which estimated that 162 kg of lead per annum was consumed in lead acetate-based hair dye products in West Germany (Cohen and Roe, 1991).

During wastewater treatment, lead primarily partitions to sewage sludge, which is converted into biosolids. Therefore, terrestrial organisms may be exposed to lead following the repeated application of lead-containing biosolids to land. Although lead(2+) emissions to wastewater from hair dyes will be small compared to other sources, particularly that from infrastructure, this exposure pathway requires consideration.

According to the National Biosolids Research Program, the average lead concentration in biosolids is 64 mg/kg (Warne, et al., 2008) and the average lead concentration of agricultural soils is approximately 20 mg/kg (SA EPA 2009). For the most stable and least contaminated biosolids (Grade C1) the maximum permissible lead concentrations range from 150 to 300 mg/kg (dry weight) (National Water Quality Management Strategy, 2004). The use of Grade C1 biosolids is unrestricted and therefore the limits for lead contamination in biosolids are also the maximum concentration limits for lead in soil (National Water Quality Management Strategy, 2004). In South Australia, lead was removed from the list of contaminants to be monitored in biosolids as lead concentrations were deemed unlikely to significantly perturb background soil concentrations (SA EPA 2009).

## Environmental Effects

It is expected that the environmental effects of lead(2+) salts in this group will be determined by the release of lead(2+) ions into the environment. Lead is recognised to be a highly toxic environmental contaminant (UNEP, 2010; 2014). Therefore, the assessment of the effects of chemicals in this group will focus on the ecotoxicity of ionic lead.

The assessment of the aquatic toxicity of ionic lead in this assessment distinguishes between 'total lead' ( $Pb_{total}$ ) and 'dissolved lead' ( $Pb_{diss}$ ) exposure concentrations. The dissolved lead concentration is usually a more reliable indicator of the concentration of bioavailable forms of lead in solution and provides a more useful toxicity indicator value for comparative hazard evaluation and risk assessment.

The dissolved lead concentration is the concentration of lead that remains in water following filtration of a water sample through a 0.45  $\mu m$  filter (ANZECC, 2000b). The dissolved lead fraction includes many simple ionic lead species and other (typically low to moderate molecular weight) inorganic and organic complexes of the lead(2+) ion. The speciation of lead in the dissolved fraction can vary greatly depending on the chemistry of the water in which the lead ion is dissolved.

## Effects on Aquatic Life

Bioavailable forms of lead(2+) are very toxic to aquatic life in short and long term exposures. The toxicity of ionic lead to aquatic organisms is strongly influenced by water chemistry.

### Acute toxicity

The following measured acute median lethal concentrations (LC50s) and median effective concentrations (EC50s) for model organisms across three trophic levels are presented together with relevant water chemistry parameters from studies published in



the scientific literature. All studies were conducted on freshwater species using soluble salts of lead(2+) according to standard test guidelines:

Taxon	Endpoint	Method
Fish	96 h LC50 = 169 µg Pb <sub>diss</sub> /L	<i>Pimephales promelas</i> (fathead minnow) – 8 day old larvae Hardness (CaCO <sub>3</sub> ) = 26 mg/L, pH = 6.4, dissolved organic carbon (DOC) = 1.4 mg C/L (Mager, et al., 2011)
	96 h LC50 = 790 µg Pb <sub>diss</sub> /L	<i>Pimephales promelas</i> – 8 day old larvae Hardness (CaCO <sub>3</sub> ) = 24 mg/L, pH = 8.2, DOC = 1.5 mg C/L (Mager, et al., 2011)
Invertebrates	48 h LC50 = 425 µg Pb <sub>diss</sub> /L	<i>Ceriodaphnia dubia</i> (daphnid) – neonates <24 hours old Hardness (CaCO <sub>3</sub> ) = 41 mg/L, pH = 7.8, DOC = 2.7 mg C/L (Mager, et al., 2011)
	48 h LC50 = 3116 µg Pb <sub>diss</sub> /L	<i>Ceriodaphnia dubia</i> –neonates <24 hours old Hardness (CaCO <sub>3</sub> ) = 106 mg/L, pH = 8.2, DOC = 15.6 mg C/L (Mager, et al., 2011)
Algae	72 h EC50 = 72 µg Pb <sub>diss</sub> /L (growth rate)	<i>Pseudokirchneriella subcapitata</i> (green algae) Hardness (CaCO <sub>3</sub> ) = 24.3 mg/L, pH = 6.0, DOC = 2.1 mg C/L (De Schampelaere, et al., 2014)
	72 h EC50 = 21 µg Pb <sub>diss</sub> /L (growth rate)	<i>Pseudokirchneriella subcapitata</i> Hardness (CaCO <sub>3</sub> ) = 24.3 mg/L, pH = 7.6, DOC = 2.1 mg C/L (De Schampelaere, et al., 2014)

## Chronic toxicity

The following effective concentrations for 10% of the test population (EC10) for the chronic effects of dissolved lead(2+) on model organisms across three trophic levels are presented together with relevant water chemistry parameters as reported in the cited scientific literature:

Taxon	Endpoint	Method
Fish	69 d EC10 = 26 µg Pb <sub>diss</sub> /L (survival)	<i>Oncorhynchus mykiss</i> (rainbow trout) – early life stage test Hardness (CaCO <sub>3</sub> ) = 20 mg/L, pH = 6.75, DOC = 1 mg C/L (Mebane, et al., 2008)
Invertebrates	7 d EC10 = 67 µg Pb <sub>diss</sub> /L	<i>Ceriodaphnia dubia</i> Hardness (CaCO <sub>3</sub> ) = 90.1 mg/L, pH = 7.6, DOC = 3.3 mg C/L (Nys, et al., 2014)
Algae	72 h EC10 = 6.2 µg Pb <sub>diss</sub> /L	<i>Pseudokirchneriella subcapitata</i> Hardness (CaCO <sub>3</sub> ) = 24.3 mg/L, pH = 7.6, DOC = 2.1 mg C/L (De Schampelaere, et al., 2014)

The acute and chronic aquatic toxicity of ionic lead in freshwater is strongly influenced by water hardness, pH and dissolved organic carbon (ANZECC, 2000b). The relative importance of these three water chemistry parameters in modifying toxicity depends on the species. However, it is generally assumed that the highest toxicity will occur under exposure conditions where ionic lead has the greatest bioavailability. The maximum bioavailability of ionic lead in freshwater is expected in waters that are of low hardness (53.6 mg/L as CaCO<sub>3</sub> (mean)) and acid to neutral pH, and where the DOC is low (ca. 1 mg C/L). Surface freshwaters with this water chemistry were identified as a 'reasonable worst case' exposure scenario for establishing standards for the protection of freshwater species from the aquatic toxicity of ionic lead in Europe under the Water Framework Directive (European Commission, 2011).

The bioavailability of lead(2+) is reduced by complexation with dissolved organic matter and it is known that high levels of DOC can significantly reduce the aquatic toxicity of ionic lead in freshwater. For example, there is a linear relationship between DOC and the concentration of dissolved lead that causes 20% cumulative mortality in larval fathead minnow after 10 days of continuous exposure (Grosell, et al., 2006). This correlation holds under conditions where variations in other key water chemistry parameters are minimised: pH 7.4–8; hardness (as CaCO<sub>3</sub>) = 19–25 mg/L. Based on this correlation, dissolved lead is 73 times less toxic to larval fathead minnow in water where DOC is 10 mg C/L as compared with water with low levels of DOC (1.2 mg C/L). Dissolved organic carbon (as humic acid) is also known to reduce the accumulation of ionic lead from water by fathead minnow in long-term exposures, which may be relevant to the chronic toxicity of lead under environmentally relevant exposure conditions (Mager, et al., 2010).

## Effects on Sediment-Dwelling Life

Bioavailable forms of lead(2+) are very toxic to sediment-dwelling organisms.

The toxicity of lead to sediment-dwelling organisms has been summarised in the rationale and background information to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Exposure to sediment contaminants for benthic organisms is assumed to principally involve pore waters. The available no-observed effect concentration (NOEC) value equivalents for select sediment-dwelling organisms (corrected to a CaCO<sub>3</sub> concentration of 30 mg/L) include a NOEC of 5.1 µg Pb/L for the amphipod *Gammarus pseudolimnaeus* and a NOEC of 28 µg Pb/L for the midge *Tanytarsus dissimilis* (ANZECC, 2000b). However, toxicity is highly dependent on sediment chemistry, which is complex and depends on a range of variable environmental parameters such as dissolved oxygen, pH and the geochemistry of sediment particles (ANZECC, 2000b). In particular, the presence of natural organic matter and the formation of sulfides will affect lead bioavailability. These factors must also be considered when determining the toxicity of lead(2+) to sediment-dwelling species.

## Effects on Terrestrial Life

Bioavailable forms of lead(2+) are toxic to terrestrial organisms.

The toxicity of lead to terrestrial organisms has been summarised in Schedule B5c of the *National Environment Protection (Assessment of Site Contamination) Measure 1999* (Cwlth) that was updated in 2013 (Commonwealth of Australia, 2013). Lead is strongly adsorbed to organic matter in soil and therefore bioavailability is typically limited. Mean NOEC values for terrestrial invertebrates range from 129 milligrams of lead per kilogram of soil (mg Pb/kg soil) for the earthworm *Dendrobaena rubida* to 1797 mg Pb/kg soil for the springtail *Fautrix candida*. Plants are also susceptible to lead toxicity, with mean NOEC values in a range from 50 mg Pb/kg soil for barley (*Hordeum vulgare*) to 546 mg Pb/kg soil for the Loblolly pine (*Pinus taeda*). Reproductive toxicity and impaired growth are listed as the most common toxic effects (Commonwealth of Australia, 2013).

## Predicted No-Effect Concentration (PNEC)

The primary environmental effects of the chemicals in this group are expected to be caused by the release of lead(2+) ions. Given that the focus of this assessment is the release of lead to wastewater, guideline values for lead in soils and aquatic systems were considered.

In place of a PNEC for the soil compartment for lead(2+), the added contaminant limit published for lead in the *National Environment Protection (Assessment of Site Contamination) Measure 1999* has been used (Commonwealth of Australia, 2013). This value represents the level above which further investigation or evaluation is required after considering naturally occurring background levels. For soils where the contaminant has been present for less than two years (i.e. a freshly contaminated soil where the toxic effects of lead are expected to be greater than in aged or leached soils), the contaminant limit for protection of 99% of species is 110 mg added Pb/kg soil (Commonwealth of Australia, 2013).

In place of PNECs for aquatic and sediment compartments for this ionic component, the default guideline values published for lead in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality have been used. These values represent thresholds above which further assessment of potential toxicity may be required to ensure environmental quality. For freshwater ecosystems with low water hardness (30 mg/L CaCO<sub>3</sub>), a high reliability guideline value for protection of 95% of species has been determined to be 3.4 µg Pb/L. The equivalent values for the protection of marine and sediment-dwelling species are 4.4 µg Pb/L and 50 mg Pb/kg (dry weight), respectively (ANZECC, 2000a).

The default guideline values provided for lead in the aquatic environment are not intended to be applicable for all situations. The Guidelines provide options to refine guideline values for metal ions by taking into account local variations in bioavailability that result from differences in the chemistry of natural waters (ANZG, 2018). These methods can be used to provide a more accurate prediction of the adverse effect concentration of ionic lead in a specific water body if the values for key water chemistry parameters are available. This approach can be useful for site-specific risk assessments but is beyond the scope of this assessment.

## Categorisation of Environmental Hazard

It is not currently possible to categorise the environmental hazards of metals and other inorganic chemicals according to standard persistence, bioaccumulation and toxicity (PBT) hazard criteria. These criteria were developed for organic chemicals and do not take into account the unique properties of inorganic substances and their behaviour in the environment (UNECE, 2007; US EPA, 2007).

Therefore, environmental hazard categorisation according to domestic PBT criteria has only been performed for the organic components of the chemicals in this group, as presented below:

## Persistence

Not Persistent (Not P). Based on results obtained from ready biodegradation studies, the organic components of all chemicals in this group are categorised as Not Persistent.

## Bioaccumulation

Not Bioaccumulative (Not B). Based on the high water solubility of short-chain carboxylic acids, the organic components of all chemicals in this group are categorised as Not Bioaccumulative.

## Toxicity

Not Toxic (Not T). Based on available acute ecotoxicity values greater than 1 mg/L, and chronic ecotoxicity values greater than 0.1 mg/L, the organic components of all chemicals in this group are categorised as Not Toxic.

## Summary

The organic components of methanesulfonic acid, lead(2+) salt; formic acid, lead(2+) salt; acetic acid, lead(2+) salt; acetic acid, lead(2+) salt, trihydrate; lead, bis(acetato-O)tetrahydroxytri-; butanedioic acid, 2,3-dihydroxy- [R-(R\*,R\*)]-, lead(2+) salt (1:1); 1,2,3-propanetricarboxylic acid, 2-hydroxy-, lead(2+) salt (2:3); 1,2,3-propanetricarboxylic acid, 2-hydroxy-, lead salt; and 1,2,3-propanetricarboxylic acid, 2-hydroxy-, lead(2+) salt (2:3), trihydrate are all categorised as:

- Not P
- Not B
- Not T

An environmental hazard categorisation for the inorganic lead component of the chemicals in this group has not been assigned for the reasons discussed above. Nevertheless, there is an international consensus that bioavailable forms of lead are highly toxic to the environment and that lead bioaccumulates in most organisms (UNEP, 2010; 2014).

## Risk Characterisation

Risk quotients (RQs) have not been calculated for these chemicals.

The chemicals in this group contain lead(2+) ions, which can be released into the environment from industrial applications and from cosmetic uses in the case of lead acetates.

Anthropogenic emissions of lead to the environment are acknowledged to be of concern, both domestically and internationally, due to the bioaccumulation properties and high toxicity of bioavailable forms of lead. Environmental contamination by lead is of particular concern because high exposure to lead compounds can cause neurological defects and reproductive toxicity across a range of organisms, including humans, plants and animals (UNEP, 2010).

However, the release of lead to the environment in Australia from the use of chemicals in this group is expected to be a negligibly small fraction of the amount of lead released from other sources including infrastructure. Furthermore, there are extensive national guidelines for lead in biosolids, soils, and aquatic systems which can be used to identify and manage risks from anthropogenic lead emissions. Adherence to these guidelines and requirements is expected to be sufficient to manage the risk both to the aquatic and terrestrial environments from uses of the lead compounds in this group.

## Key Findings

Chemicals in the Water Soluble Lead(2+) Salts group are expected to have uses in mineral processing, chemical manufacture, as industrial intermediates, in electroplating, and in progressive hair dyes.

The principal environmental concern for lead salts in this group is the potential for release of soluble forms of ionic lead to wastewater. This poses a concern because lead and lead compounds are considered to be highly significant environmental contaminants. Lead acetates are the compounds in this group most likely to emit lead to STPs based on their use in progressive hair dyes. However, emissions from this source are expected to contribute a negligible proportion of the total anthropogenic lead load entering the environment.

Based on the currently available information, industrial uses of the lead compounds in this group pose a low risk to the aquatic and terrestrial environments in Australia.

## Recommendations

The chemicals in this group are not prioritised for further evaluation.

## Environmental Hazard Classification

In addition to the categorisation of environmental hazards according to domestic environmental thresholds presented above, the classification of the environmental hazards of nitric acid, lead(2+) salt; methanesulfonic acid, lead(2+) salt; lead fluoride (PbF<sub>2</sub>); lead chloride (PbCl<sub>2</sub>); lead bromide (PbBr<sub>2</sub>); lead iodide (PbI<sub>2</sub>); borate(1-), tetrafluoro-, lead(2+) (2:1); formic acid, lead(2+) salt; acetic acid, lead(2+) salt; acetic acid, lead(2+) salt, trihydrate; lead, bis(acetato-O)tetrahydroxytri-; butanedioic acid, 2,3-dihydroxy- [R-(R\*,R\*)]-, lead(2+) salt (1:1); 1,2,3-propanetricarboxylic acid, 2-hydroxy-, lead(2+) salt (2:3); 1,2,3-propanetricarboxylic acid, 2-hydroxy-, lead salt; and 1,2,3-propanetricarboxylic acid, 2-hydroxy-, lead(2+) salt (2:3), trihydrate according to the third edition of the United Nations' Globally Harmonised System of Classification and Labelling of Chemicals (GHS) are presented below (UNECE, 2009):

Hazard	GHS Classification (Code)	Hazard Statement
Acute Aquatic	Category 1 (H400)	Very toxic to aquatic life
Chronic Aquatic	Category 1 (H410)	Very toxic to aquatic life with long lasting effects

The salts in this group are classified as Acute Aquatic Category 1 as the dissolved lead(2+) ion concentrations accessible exceed all acute toxicity values for lead identified in this assessment for aquatic species. Similarly, the dissolved metal concentrations exceed all chronic toxicity endpoints listed above for aquatic species. Also, lead(2+) bioaccumulates in aquatic organisms. Hence, these salts are all categorised as Chronic Aquatic Category 1 according to the GHS classification strategy for metals and metal compounds (UNECE, 2007).

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