Lead acetates: Human health tier III assessment

Chemical Name on the Inventory	CAS Number
Acetic acid, lead(2+) salt lead diacetate	301-04-2
Acetic acid, lead(4+) salt lead tetraacetate	546-67-8
Lead, bis(acetato- O)tetrahydroxytri- lead subacetate	1335-32-6
Acetic acid, lead(2+) salt, trihydrate lead acetate trihydrate	6080-56-4
Acetic acid, lead salt, basic lead acetate basic	51404-69-4

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 4 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 3 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 is being assessed at Tier III because the Tier II assessment indicated that it needed further investigation. The report should be read in conjunction with the Tier II assessment.

For more detail on this program please visit: www.nicnas.gov.au

Acronyms & Abbreviations

Synopsis

Under the Inventory Multi-tiered Assessment and Prioritisation (IMAP) Framework, the Tier II human health (HH) assessment for chemicals in the lead acetate group determined that further work is required to examine any new information and hence the potential health risk associated with use of manufactured and/or imported hair dyes containing lead acetate. A Tier III HH assessment was recommended.

There is no evidence for a safe level of lead exposure although trace amounts of lead in food, drinking water, air, dust, soil and consumer products are generally unavoidable (NHMRC, 2016; WHO, 2018). Based on exposure estimates for transdermal absorption and hand-to-mouth transfer of lead in this assessment, the use of lead acetate in hair dye can pose a significant health risk, particularly to users of progressive hair dyes, their pregnant partners and children. Lead exposure from use of hair cosmetics is preventable; and therefore, the restriction proposed in this assessment is intended to address this issue.

The Tier II HH assessment for lead acetates remains valid and available online at nicnas.gov.au. The Tier II and Tier III HH reports for lead acetates should be read together.

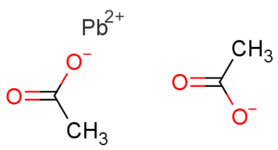
Rationale for Tier III HH Assessment

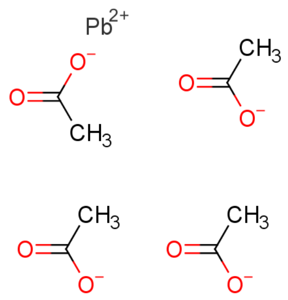
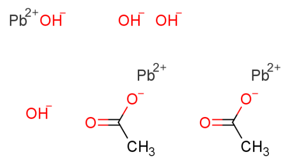
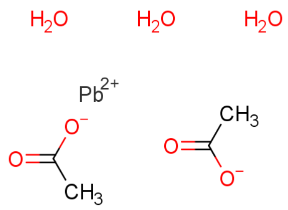
Cosmetic use of lead acetate has been banned worldwide, including Canada, European Union (EU), New Zealand, Association of Southeast Asian Nations, and recently in United States of America (USA), on a number of grounds such as 'carcinogenic, mutagenic, reprotoxic' (CMR) hazard classification, cumulative burdens of lead, or 'there is no longer a reasonable certainty of no harm' from its use as colour additive in hair dye (SCCNFP, 2004; Koniecki & Healey, 2008; US FDA, 2018).

In the USA, prior to 3 December 2018, lead acetate was listed as safe for use in cosmetics intended for colouring hair on the scalp at up to 0.6 % (w/v), subject to certain restrictions and labelling requirements (US FDA, 2018). Given the well-established toxicity of lead, together with newly available information on dermal absorption of lead and lead compounds, public concerns have been raised and were heightened by a colour additive petition submitted in 2017 to the US Food and Drug Administration for review (see US FDA, 2018 for details). For the intended use conditions of lead acetate, Mielke et al. (1997) demonstrated that some hair dyes sold nationwide in chemists or pharmacies contain more lead than paint and this may cause harm to consumers, particularly through hand-to-mouth pathways.

In Australia, lead acetates can be used as cosmetic ingredients in hair dye without restriction. Therefore, NICNAS conducted this Tier III HH assessment to quantify the potential exposure from this use in order to determine if a risk management recommendation for public health is warranted.

Chemical Identity

Chemical name on the Inventory and Synonyms	CAS Number	Structural Formula	Molecular Formula	Molecular Weight
Acetic acid, lead(2+) salt lead diacetate	301-04-2		$C_2H_4O_2.{}^1/_2Pb$	325.29

Chemical name on the Inventory and Synonyms	CAS Number	Structural Formula	Molecular Formula	Molecular Weight
Acetic acid, lead(4+) salt lead tetraacetate	546-67-8		$C_2H_4O_2$.${}^1/_4$Pb	443.38
Lead, bis(acetato- O)tetrahydroxytri- lead subacetate	1335-32-6		$C_4H_{10}O_8Pb_3$	807.72
Acetic acid, lead(2+) salt, trihydrate lead acetate trihydrate	6080-56-4		$C_2H_4O_2$.${}^3/_2H_2O$.${}^1/_2$ Pb	379.33
Acetic acid, lead salt, basic lead acetate basic	51404-69-4	**No Structural Diagram Available**	unspecified	

Import, Manufacture and Use

Australian

Lead acetate has reported cosmetic use as a component of hair treatments. This is the only cosmetic use of lead at above 250 mg/kg (0.025 %) allowed under the Customs (Prohibited Imports) Regulations 1956 (see **Restrictions**).

Lead acetate (except lead diacetate, CAS No. 301-04-2) has reported site-limited uses in the manufacture of substances (Sigma-Aldrich SDS).

International

Cosmetic use of lead acetate in hair colouring, bleaching and conditioning products has been identified through the US Household Products Database; Personal Care Products Council's International Nomenclature Cosmetic Ingredient (INCI) Dictionary and Handbook; and international assessments by National Toxicology Program (NTP, 2012) and the US Food and Drug Administration (US FDA, 2018).

Restrictions

Australian

Lead or lead compounds are listed under the following Schedules in:

1. The Poisons Standard—the Standard for the Uniform Scheduling of Medicines and Poisons (SUSMP 24; June 2019):

Part 2: Control on Medicines and Poisons

Section One: Labels

1.4(f) if the poison is a lead-based pigment included in automotive paint, the proportion may be expressed as the maximum content of the lead that may be present in the non-volatile content of the paint.

Section Seven/Appendix I: Paint or Tinters

7.1(2) A person must not manufacture, sell, supply or use a paint or tinter containing more than 0.1% lead (the proportion of lead for the purposes of this section is calculated as a percentage of the element present in the non-volatile content of the paint).

Schedule 5

LEAD COMPOUNDS in preparations for use as hair cosmetics.

Schedule 5 chemicals are labelled with 'Caution'. These are ‘substances with low potential for causing harm, the extent of which can be reduced through the use of appropriate packaging with simple warnings and safety directions on the label’.

Schedule 6

LEAD COMPOUNDS except:

a) when included in Schedule 4 or 5;

b) in paints, tinters, inks or ink additives;

c) in preparations for cosmetic use containing 100 mg/kg or less of lead;

d) in pencil cores, finger colours, showcard colours, pastels, crayons, poster paints/colours or coloured chalks containing 100 mg/kg or less of lead; or

e) in ceramic glazes when labelled with the warning statement:

CAUTION – Harmful if swallowed. Do not use on surfaces which contact food or drink.

written in letters not less than 1.5 mm in height.

Schedule 6 chemicals are labelled with 'Poison'. These are ‘substances with a moderate potential for causing harm, the extent of which can be reduced through the use of distinctive packaging with strong warnings and safety directions on the label’.

Schedule 10

LEAD COMPOUNDS in paints, tinters, inks or ink additives except in preparations containing 0.1 per cent or less of lead calculated on the non-volatile content of the paint, tinter, ink or ink additive.

Schedule 10 (previously Appendix C) chemicals are ‘substances of such danger to health as to warrant prohibition of sale, supply and use’. Substances which are prohibited for the purpose or purposes listed for each poison.

2. Customs (Prohibited Imports) Regulations 1956

Schedule 2 (Goods the importation of which is prohibited unless the permission in writing of the Minister or an authorised person has been granted):

Item 2: Toys coated with a material the non-volatile content of which contains more than 90 mg/kg of lead.

Item 3: Cosmetic products containing more than 250 mg/kg of lead or lead compounds (calculated as lead), except products containing more than 250 mg/kg of lead acetate designed for use in hair treatments.

Item 6: Money boxes coated with a material that contains more than 90 mg/kg of lead.

Item 7: Pencils or paint brushes coated with a material the non-volatile content of which contains more than 90 mg/kg of lead.

Item 34: Erasers, resembling food in scent or appearance, that contain more than 90 mg/kg of lead.

International

Lead and lead compounds (including lead acetate) are listed in the following:

- European Union (EU) Cosmetics Regulation Annex II (List of substances prohibited in cosmetic products) (CosIng; SCCNFP, 2004). Lead diacetate (CAS No. 301-04-2) and lead acetate basic (CAS No. 51404-69-4) are also listed in the Candidate List of substances of very high concern (SVHC) for eventual inclusion in REACH Regulation Annex XIV ‘Authorisation List’ (ECHA, 2012–13). In the EU, companies could have legal obligations if the chemical that they produce, supply, or use is included in the candidate list, either as substances, in mixtures, or present in articles.
- US FDA Colour Additive Regulations: termination of listing of lead acetate for use in cosmetics intended for colouring hair on the scalp, which is effective 3 December 2018.
- Canada Cosmetic Ingredient Hotlist (List of ingredients that are prohibited for use in cosmetic products) (Koniecki & Healey, 2008).
- New Zealand Cosmetic Products Group Standard Schedule 4 (Components cosmetic products must not contain) (NZ EPA, 2017).
- Association of Southeast Asian Nations Cosmetic Directive Annex II Part 1 (List of substances which must not form a part of the composition of cosmetic products) (ASEAN, 2018).

Existing Work Health and Safety Controls

All the five lead acetates assessed under Tier II HH IMAP are classified as hazardous with the following hazard categories and hazard statements for human health in the Hazardous Chemical Information System (HCIS) (Safe Work Australia):

- Acute toxicity – Category 4; H332 (Harmful if inhaled)
- Carcinogenicity – Category 2; H351 (Suspected of causing cancer)
- Germ cell mutagenicity – Category 2; H341 (Suspected of causing genetic defects)
- Reproductive toxicity – Category 1A; H360Df (May damage the unborn child. Suspected of damaging fertility)

Lead subacetate (CAS No. 1335-32-6) has additional hazard classification as follows:

- Specific target organ toxicity (repeated exposure) – Category 2; H373 (May cause damage to organs through prolonged or repeated exposure)

Lead diacetate (CAS No. 301-04-2) has additional hazard classification as follows:

- Acute toxicity – Category 4; H302 (Harmful if swallowed)
- Specific target organ toxicity (repeated exposure) – Category 2; H373 (May cause damage to organs through prolonged or repeated exposure)

Public Exposure Assessment

According to the National Health and Medical Research Council (NHMRC, 2016), public exposure to lead has significantly dropped in Australia as a result of regulations and controls on the addition of lead to paint, petrol and consumer goods (toys, cosmetics and cans). The NHMRC statement recommends that 'if a person has a blood lead level (BLL) greater than five micrograms per decilitre (5 µg/dL), the source of exposure should be investigated and reduced, particularly if the person is a child or pregnant woman'. The 5 µg/dL level is the estimated average 'background' BLL among Australians and not designated a safe threshold for lead exposure. There are also recommendations that every effort should be made to minimise lead exposure in everyday environments, such as in food, drinking water (particularly from some plumbing products), air, dust, soil, and consumer goods (NHMRC, 2016; enHealth, 2018).

Lead acetate is currently used as a colour additive in hair dye—the only cosmetic use of lead which has no restrictions in Australia. There is no Australian information available on the concentration, use pattern, or measured consumer exposure from this specific use of lead acetate, although the product range identified overseas is known to be available in Australia. Where relevant, identified overseas exposure scenarios and modelled data for hair cosmetic use may be considered in deriving Australian exposure estimates.

The product is used by pouring the dye into the palm of the hand and massaging into the hair. The user of the product is; therefore, exposed dermally through the hands and the scalp. Lead residues will remain on the hands and on a comb. Further, the dye user may touch surfaces such as tap handles and bathroom tiles, with potential to transfer lead to other members of the household. Measurements of lead residues associated with hair dye use have been reported in literature (Mielke et al., 1997).

Methodology for assessing exposure

In this assessment, a 'reasonable worst-case' approach is used for modelling hair dye use of lead acetate, in which estimates are based on worst-case, but plausible, exposure scenarios and default values. It is believed that this approach will fundamentally consider exposures of all individuals within the target population.

Although absorption is limited, lead can enter human body by dermal absorption. A review of nonclinical and clinical studies by US FDA (2018) has demonstrated transdermal penetration and systemic distribution of lead and lead compounds (including lead acetate in progressive hair dye) to organs and tissues, with percentages of absorption ranging from 0.018 to 29 %. These values may or may not take into account for amounts of lead localising in sweat, saliva and other extracellular fluid compartments after transdermal absorption or remaining bound to skin proteins for weeks before entering the bloodstream (Lilley et al. 1988; Stauber et al. 1994; Thier et al., 2003; cited in US FDA, 2018). The review showed that conditions of lead application such as occlusion, wet or dry formulations, use of saturating concentrations or shampoos containing sodium lauryl sulfate (SLS) can affect the kinetics and extent of lead absorption (US FDA, 2018). Such uncertainty factors are further discussed in the context of the exposure assessment and risk characterisation below.

Lead acetate is used mainly in progressive hair dyes for men. The product requires pouring the dye into the palm of hand (directly) and daily applying like a hair groomer with fingers until hair reaches desired shade (about 2–3 weeks), thereafter applying once or twice a week to maintain the natural look. Manufacturers' instructions did not recommend any use of gloves or shampooing hair immediately after applying the dye. Daily application amounts can vary greatly with the amount of hair and if the users need to cover grey totally until hair feels slightly damp. Such use conditions have suggested a high potential for inadvertent ingestion exposure of lead acetate, even when hair dyes are used as directed (Mielke et al., 1997; Colour Additive Petition cited in US FDA, 2018). In the range of hair dye products known to be used in Australia, the concentration of lead acetate, if present, is assumed to be 0.6 % (w/v), which is the maximum concentration allowed in the USA for use in cosmetic products intended for colouring hair on the scalp, prior to 3 December 2018.

In this assessment, inadvertent ingestion of lead is considered an important route of exposure for both users and non-users (e.g. users' pregnant partners and their children) through hand-to-mouth and object-to-mouth activities. Children (because of their mouthing behaviours) and users with habitual nail biting, finger sucking or repeatedly touching their mouth are likely to increase the chance of ingesting lead from their hands and contaminated objects or surfaces (e.g. by touching a comb, blow dryer, product container, tap handle, telephone, and/or by wiping their dry treated hair) (Mielke et al., 1997; Cherrie et al., 2006).

Inhalation exposure to lead acetate from hair dye use is considered negligible as the product is not intended to be used in aerosol, spray or powder forms.

Therefore, exposure of hair dye users to lead acetate is estimated for both dermal and incidental ingestion routes (hand-to-mouth and object-to-mouth). Given the lack of experimental information on the typical use of lead acetate in progressive hair dyes, the exposure estimates are based on the conservative model parameters as per the guidelines by the Scientific Committee on Consumer Safety (SCCS, 2018) and the Office of Environmental Health Hazard Assessment (OEHHA, 2008; 2011).

For the purpose of this assessment, lead intakes from incidental ingestion are estimated for both adults and children, using representative exposure scenarios where model parameters and experimental values are available and considered relevant to an event of hair dye use. For hair dye users, lead intakes are calculated from directly handling the lead-containing hair dyes (with and without hand washing) then touching their mouth, plus indirectly from touching deposited lead on a tap handle or a comb, then transferring lead to a sandwich or an apple and eating the food. For users' children, lead intakes are calculated from touching the lead deposit on the tap handle then directly mouthing their fingers, plus indirectly transferring lead to a sandwich or an apple from their contaminated palms and eating the food. There are many other household items, e.g. bathroom tiles that can be similarly contaminated with lead from the use of hair dyes containing lead acetate and these will be in addition to the modelled exposure scenarios illustrated below.

Model for exposure of hair dye users

The use pattern of the progressive hair dye containing lead acetate is considered combining those of hair styling products (leave-on daily application for first three weeks) and of semi-permanent hair dyes (twice a week thereafter).

Dermal exposure of was modelled by:

- assuming the dermal bioavailability of lead (5 %), based on the US FDA (2018) review of dermal absorption studies, with percentages of absorption ranging from 0.018 to 29 %. This includes recognition of deficiencies identified in these dermal absorption studies, in particular the Moore et al. (1980) study, which reported a value of 0–0.3 % for the uptake of lead acetate from 'hair-darkening' cosmetic preparations.
  The SCCS (2018) indicates that the default value of 50 % bioavailability may also be used in cases where the experimental absorption data are absent or inadequate.
- assuming the lead acetate concentration of 0.6 % (w/v) in progressive hair dyes available in Australia, based on the maximum concentration allowed in the USA prior to 3 December 2018 (US FDA, 2018).
- using default values from the SCCS (2018) Notes of Guidance for retention factor and typical use pattern (amount and frequency of use in the general population) of various hair cosmetic categories.
  - For hair styling products, the applied amount of 57.4 mg/kg bw/day is based on a probabilistic calculation among consumers in different European Member States, which was normalised to the body weight of the study participants.
  - Given hair dye products are not intended to be applied on a daily basis, 'the exposure value is the actual dose on the exposure days, and not the daily dose averaged out (and thus divided!) over the whole year', according to the international guidance (ECHA, 2012; SCCS, 2018).
- using the Australian default average body weight (85 kg) for men (enHealth, 2012).
- calculating BLLs added to the background exposure, based on the JECFA (2011) analysis of the kinetic relationship between dietary exposure to lead and BLL, which identified a range of 0.023–0.07 µg/dL per 1 µg/day (total exposure) for adults. As this parameter is used to calculate the incremental increase of BLL, calculations are conducted on a per person basis, not per kg bw.

The daily systemic exposure doses (SEDs) through dermal route are calculated and shown in **Table 1–2**. The SED is the amount expected to enter the bloodstream and; therefore, be systemically available expressed in µg/person/exposure day.

$SED = E_{dermal} \times B$ (**Equation 1**)

Where:

$E_{dermal} = A \times C \times RF \times BW$ (**Equation 2**)

E_{dermal} = external dermal exposure (µg/person/exposure day)

B = bioavailability by dermal absorption (%)

A = daily applied amount (mg/kg bw/day)

C = concentration of lead (%)

RF = default retention factors for leave-on hair cosmetics

BW = body weight (kg)

Table 1: Estimated systemic exposure dose (SED) and added blood lead level (BLL) through dermal exposure to progressive hair dyes containing lead acetate, adopting the use pattern of hair styling products

Use pattern I of lead acetate hair dyes: leave-on daily application for first three weeks	Adopting the use pattern of hair styling products (SCCS, 2018)	Units
Daily applied amount (A)	57.40	mg/kg bw/day
Concentration of lead (C)	0.60%	maximum concentration allowed in the USA prior to 3 December 2018
Retention factor (RF)	0.10	default value for leave-on cosmetics
External Dermal Exposure ($E_{dermal} = A \times C \times RF \times BW$)	2927.40	µg/person/exposure day (body weight BW=85 kg for men)
Bioavailability by dermal absorption (B)	5.00%	assumption value
Systemic exposure dose ($SED = E_{dermal} \times B$)	146.37	µg/person/exposure day

Use pattern I of lead acetate hair dyes: leave-on daily application for first three weeks	Adopting the use pattern of hair styling products (SCCS, 2018)	Units
Added blood lead level (BLL) (JECFA, 2011: 0.07 µg/dL per 1 µg/day)	**10.25**	**µg/dL**

Table 2: Estimated systemic exposure dose (SED) and added blood lead level (BLL) through dermal exposure to progressive hair dyes containing lead acetate, adopting the use pattern of semi-permanent hair dyes

Use pattern II of lead acetate hair dyes: twice a week thereafter	Adopting the use pattern of semi-permanent hair dyes (SCCS, 2018)	Units
Calculated daily applied amount (A)	411.76	mg/kg bw/day (35 mL applied per person BW=85 kg, 1 g/mL density)
Frequency of application	--	low frequency of use*
Concentration of lead (C)	0.60%	maximum concentration allowed in the USA prior to 3 December 2018
Retention factor (RF)	0.01	default value for rinse-off cosmetics
External Dermal Exposure ($E_{dermal} = A \times C \times RF \times BW$)	2100.00	µg/person/exposure day (body weight BW=85 kg for men)
Bioavailability by dermal absorption (B)	5.00%	assumption value
Systemic exposure dose ($SED = E_{dermal} \times B$)	105.00	µg/person/exposure day
Added blood lead level (BLL) (JECFA, 2011: 0.07 µg/dL per 1 µg/day)	**7.35**	**µg/dL**

*Given hair dyes are not intended to be applied on a daily basis, 'the exposure value is the actual dose on the exposure days, and not the daily dose averaged out (and thus divided!) over the whole year', according to the international guidance (ECHA, 2012; SCCS, 2018).

Incidental ingestion exposure was modelled by:

- adopting the OEHHA (2011) framework for hand-to-mouth transfer of lead through exposure to consumer products. Total lead intake through hand-to-mouth activity (Total Intake) is given by the sum of 'the lead intake from directly handling the product containing lead and then touching the mouth', plus 'the lead intake from handling the lead-containing product and then handling and depositing lead on an intermediate item (e.g. food), and then eating or touching the mouth with that item'.
- using lead residues on hands after use of hair dyes (with and without hand washing) and on contaminated objects (e.g. a tap handle and a comb), based on the Mielke et al. (1997) experimental study of hand-to-mouth exposure route when the lead-based hair dyes are used according to manufacturers' instructions.
- using default values for direct vs indirect hand-to-mouth contact (e.g. surface area of part of the hand touching the mouth or contaminated objects and transfer factor), based on the OEHHA (2008) Interpretive Guideline for hand-to-mouth transfer of lead through exposure to fishing tackle products, as well as the OEHHA (2011) review of hand-to-mouth activity patterns in adults.
- calculating BLLs added to the background exposure, based on the JECFA (2011) analysis of the kinetic relationship between dietary exposure to lead and BLL, which identified a range of 0.023–0.07 µg/dL per 1 µg/day for adults.

The total lead intake (Total Intake) in adults through hand-to-mouth route are calculated and shown in **Table 3**.

$$\text{Total Intake} = \text{Intake}_{direct} + \text{Intake}_{indirect}$$ (**Equation 3**)

Where:

$$\text{Intake} = L \times SA \times TF \times r \times t$$ (**Equation 4**)

L = lead loading on the hand (µg/cm^2)

SA = surface area of part of the hand in direct vs indirect hand-to-mouth contact (cm^2)

TF = default transfer factors for direct vs indirect hand-to-mouth contact

r = hourly rate of direct vs indirect hand-to-mouth contact

t = exposure time involving hand-to-mouth contact per an event of hair dye use (hour/day)

For the hair dye use scenario, the proportion transferred (TF × r × t) cannot exceed one as the source of lead (residues on hands or contaminated objects) does not stay constant over time, but is reduced to (1 - TF) after each contact and independent of the time. Therefore, the calculation does not apply recommended values for hand-to-mouth contact frequency in adults (e.g. r = 9 per hour for direct contact) and children (r = 19.6 vs 15 per hour for direct vs indirect contact, respectively) (OEHHA, 2008;

NRDC, 2009). Given the default transfer factor of TF = 0.5 or 0.25 and independent of the time, and assuming the high hourly rate for r, then the factor (TF × r × t) can be assumed to be one. For a single contact, the default transfer value (0.5 for direct contact or 0.25 for indirect contact) is used.

Table 3: Estimated total lead intake and added blood lead level (BLL) in adults from incidental ingestion through hand-to-mouth and object-to-mouth activities

Lead exposure via direct hand-to-mouth contact	with hand washing	without hand washing	Units	Sources
Lead residue on hand after use of hair dyes	80.00	700.00	µg	Mielke et al., 1997 (experimental value)
Lead loading (L) on hand	0.19	1.67	µg/cm^2	OEHHA, 2008 (surface area SA = 420 cm^2/hand for men)
Surface Area (SA) of the hand in direct contact with the mouth	19.00	19.00	cm^2	OEHHA, 2008 (assuming thee fingertips)
Proportion transferred (TF × r × t)* , 1st contact	0.50	0.50		
Maximum value*	1.00	1.00		
Intake $_{direct}$ after 1st contact	**1.81**	**15.83**	**µg/person/day**	OEHHA, 2011 (Intake = L × SA × TF × r × t)
Intake $_{direct}$ maximum	**3.62**	**31.67**	**µg/person/day**	
Lead exposure via indirect hand-to-mouth contact	Tap handle after use	Comb after use	Units	Sources
Lead residue on contaminated objects or surfaces	417.00	1804.00	µg/ft^2	Mielke et al., 1997 (experimental value)
Lead loading (L) on hand	0.45	1.94	µg/cm^2	Conversion 1 ft^2= 929.03 cm^2
Surface Area (SA) of the hand in contact with contaminated objects reaching the mouth	190.00	190.00	cm^2	OEHHA, 2008 (assuming the handling of large objects like a sandwich or an apple by most of the palm of the hands)
Proportion transferred (TF × r × t)*, 1st contact	0.25	0.25		
Maximum value*	1.00	1.00		
Intake $_{indirect}$ after 1st contact	**21.32**	**92.24**	**µg/person/day**	OEHHA, 2011 (Intake = L × SA × TF × r × t)
Intake $_{indirect}$ maximum	**85.28**	**368.94**	**µg/person/day**	
Total Intake = Intake $_{direct}$+ Intake $_{indirect}$	23.13	108.07	µg/person/day	OEHHA, 2011
(minimum and maximum lead intake values per exposure scenario)	88.90	400.61	µg/person/day	
Added blood lead level (BLL)	**1.62**	**7.56**	**µg/dL**	**after 1st contact**
(JECFA, 2011: 0.07 µg/dL per 1 µg/day for adults)	**6.22**	**28.04**	**µg/dL**	**maximum value**

*Assuming the factor (TF × r × t) approximates to one (1) as the source of lead (residues on hands or contaminated objects) does not stay constant over time, but is reduced to (1 - TF) after each contact and independent of the time. TF = transfer factor, r = hourly rate of hand-to-mouth contact, t = exposure time (hour/day). See modelling of incidental ingestion exposure for derivation.

Potential incidental ingestion exposure of users' children

Children have immature blood-brain barrier and still developing gastrointestinal, endocrine and reproductive systems, as well as a larger surface area relative to body weight than do adults (WHO, 2011). Children also have higher hand-to-mouth activities and higher rates (e.g. up to 5- to 10- fold) of lead absorption and retention, compared with adults (Mielke et al., 1997; JECFA, 2011).

Hair dye users' pregnant partners may also be exposed and lead can be transferred from the mother to the foetus or from the mother to infants via maternal milk (JECFA, 2011).

Given the children's specific biological and behaviour characteristics, exposure estimates of children to lead acetate from incidental ingestion by a shared exposure pathway following an event of hair dye use by their parents are expected to be significantly greater than those found in their parents.

Incidental ingestion exposure of users' children was modelled by:

- adopting the OEHHA (2011) framework for hand-to-mouth transfer of lead through exposure to consumer products. For children, total lead intake through hand-to-mouth activity (Total Intake) is given by the sum of the lead intake from touching contaminated objects or surfaces (e.g. a tap handle) and then directly mouthing their fingers, plus the lead intake from handling and depositing lead on an intermediate item (e.g. food) by using their contaminated palms, and then eating or touching the mouth with that item.
- using default values for direct vs indirect hand-to-mouth contact (e.g. surface area of part of the hand touching the mouth or contaminated objects and transfer factor), based on the NRDC (2009) risk assessment of toxic chemicals in flea and tick collars, as well as the OEHHA (2011) review of hand-to-mouth activity patterns in children.
- again assuming the factor (TF × r × t) approximates to one (1) as the source of lead (residues on hands or contaminated objects) does not stay constant over time, but is reduced to (1 - TF) after each contact and independent of the time. For a single contact, the default transfer value (0.5 for direct contact or 0.25 for indirect contact) is used.
- calculating BLLs added to the background exposure, based on the JECFA (2011) analysis of the kinetic relationship between dietary exposure to lead and BLL, which identified a range of 0.05–0.16 µg/dL per 1 µg/day for children.

The total lead intake (Total Intake) in children through hand-to-mouth route are calculated and shown in **Table 4**.

Table 4: Estimated total lead intake and added blood lead level (BLL) in children from incidental ingestion through hand-to-mouth and object-to-mouth activities

Lead exposure via direct hand-to-mouth contact	Tap handle	Units	Sources
Lead residue on contaminated objects or surfaces	417.00	µg	Mielke et al., 1997 (experimental value)
Lead residue on hand after touching the contaminated surfaces	208.50	µg	OEHHA, 2011 (applying a default value of 0.5 for direct transfer)
Lead loading (L) on hand	1.19	µg/cm^2	NRDC, 2009 (surface area SA = 175 cm^2 /hand for children)
Surface Area (SA) of the hand in direct contact with the mouth	20.00	cm^2	NRDC, 2009 (assuming thee fingers)
Proportion transferred (TF × r × t)*, 1st contact	0.50		
Maximum value*	1.00		
Intake $_{direct}$ after 1st contact	**11.91**	**µg/person/day**	OEHHA, 2011 (Intake = L × SA × TF × r × t)
Intake $_{direct}$ maximum	**23.83**	**µg/person/day**	
Lead exposure via indirect hand-to-mouth contact	Tap handle	Units	Sources
Lead residue on contaminated objects or surfaces	417.00	µg/ft^2	Mielke et al., 1997 (experimental value)
Lead loading (L) on hand	0.45	µg/cm^2	Conversion 1 ft^2= 929.03 cm^2
Surface Area (SA) of the hand in contact with contaminated objects reaching the mouth	88.00	cm^2	NDRC, 2009 (assuming the handling of large objects like a sandwich or an apple by most of the palm of the hands)
Proportion transferred (TF × r × t)*, 1st contact	0.25		
Maximum value*	1.00		

Lead exposure via direct hand-to-mouth contact	Tap handle	Units	Sources
Intake $_{indirect}$ after 1st contact	**9.87**	**µg/person/day**	OEHHA, 2011 (Intake = L × SA × TF × r × t)
Intake $_{indirect}$ maximum	**39.50**	**µg/person/day**	
Total Intake = Intake $_{direct}$+ Intake $_{indirect}$	21.79	µg/person/day	OEHHA, 2011
(minimum and maximum lead intake values per exposure scenario)	63.33	µg/person/day	
Added blood lead level (BLL)	**3.49**	**µg/dL**	**after 1st contact**
(JECFA, 2011: 0.16 µg/dL per 1 µg/day for adults)	**10.13**	**µg/dL**	**maximum value**

*Assuming the factor (TF × r × t) approximates to one (1) as the source of lead (residues on hands or contaminated objects) does not stay constant over time, but is reduced to (1 - TF) after each contact and independent of the time. TF = transfer factor, r = hourly rate of hand-to-mouth contact, t = exposure time (hour/day). See modelling of incidental ingestion exposure for derivation.

Uncertainties in the exposure estimation

It is acknowledged that there are always uncertainties in deriving exposure estimates. The use of measured data is always preferred. However, if Australian or biomonitoring data are not available to determine the relationship between elevated BLLs and hair dye use of lead acetate, exposure modelling is considered the most suitable approach for the purpose of this assessment.

Uncertainties in this exposure assessment arise mainly from inadequate data and assumptions made in exposure calculation, including:

- absence of Australian-specific measured consumer exposure following an event and/or repeated use of lead acetate in progressive hair dyes
- absence of Australian-specific data for the concentration and use pattern of lead acetate in progressive hair dyes
- absence of Australian-specific data for hand-to-mouth transfer of lead through exposure to lead acetate in hair cosmetics
- lack of an adequate dermal absorption study for the intended use of lead acetate in hair cosmetics
- lack of a kinetic relationship between dermal exposure to lead acetate and BLL.

There are also uncertainties concerning factors that can affect the kinetics and extent of lead absorption (US FDA, 2018), for example:

- scratched scalp which may result in increased exposure
- lead localising in sweat or bound to skin proteins for weeks before entering the bloodstream which may result in underestimation of lead dermal absorption
- conditions of lead application such as occlusion, wet or dry formulations.

For hand-to-mouth transfer, conditions of the object (e.g. pH, size, moisture or oil content) and the individual's hands (e.g. dry or sweaty), as well as physiological factors (e.g. age, fasting, nutritional calcium and iron status, pregnancy) may affect the transfer efficiency (OEHHA, 2008).

Nevertheless, the uncertainties about absence of Australian-specific data are not considered critical as the products known to be used in Australia are internationally marketed, and there are no reasons to expect behaviours of Australians to differ greatly compared to those measured in similar countries.

Risk Characterisation

Critical Health Effects

The health effects of lead and its compounds, including lead acetate, have been extensively studied and reviewed. It is agreed that there is no evidence for a safe BLL. Lead is a cumulative toxicant, affecting multiple body systems and can be harmful to people of all ages, particularly to young children. The main target for lead toxicity in both adults and children is the nervous system. BLLs in the range of 5–10 µg/dL have been found to be associated with adverse cognitive and behavioural effects (such as reduced intelligence quotient (IQ), academic achievement, attention deficit, hyperactivity and impulsivity) in children. There is also 'sufficient' evidence in adults for decreased glomerular filtration rates (GFR) at BLLs ≤5 µg/dL, increased blood pressure at ≤10 µg/dL, and increased incidences of tremor at 10 µg/dL. For BLLs >10 µg/dL, lead can damage people's cardiovascular, gastrointestinal, renal, reproductive, haematological, immunological and neurological functions (for more detail of lead effects, please see JECFA, 2011; NTP, 2012; NHMRC, 2016; US FDA, 2018; WHO, 2018; ATSDR, 2019).

Public Risk Characterisation

The reasonable worst-case scenario exposure estimates for BLLs added to the background lead level from dermal exposure (7.35–10.25 µg/dL in adults; **Table 1–2**) and from incidental ingestion through hand-to-mouth and object-to-mouth activities (1.62–28.04 µg/dL in adults and 3.49–10.13 µg/dL in children after the 1st contact and maximum values; **Table 3–4**). All indicate that the intended use of lead acetate in hair cosmetics can pose an unacceptable risk to human health.

Even when the hair dyes are used as directed, offspring of pregnant partners and children of users are particularly at high risk of neurodevelopmental and behavioural effects because they are more sensitive to the effects of lead than adults. Children may have greater BLLs as a result of hand-to-mouth and object-to-mouth activities, along with their greater absorption and retention of ingested lead. In the OEHHA (2011) guideline, the lead exposure through hand-to-mouth pathway is considered the most concern for toddlers, because of their increased mobility compared with infants, and their more frequent hand-to-mouth activities compared with older children.

All the exposure estimates used are based on worst-case scenario and occurrences, such as contact with contaminated tap handles which are unlikely to occur on each application of the product. However, the magnitudes of the increases in BLL under these estimates indicate that scattered occurrences of worst-case outcomes together with more common exposures, for example up to 10 % of the worst-case exposures, pose a public health risk that requires controls.

Furthermore, lead exposures are cumulative and the exposure scenarios modelled in this assessment are considered representative of many other exposure scenarios resulting from residues on hands or contaminated objects, e.g. bathroom tiles, which may occur in addition to the exposures modelled in this assessment, after an event of hair dye use.

NICNAS Recommendation

Further risk management is required. Based on the unacceptable health risk as a result of elevated BLLs following an event of hair dye use of lead acetate at 0.6 % (w/v), it is recommended that risks to public health and safety from the potential use of lead acetate in hair cosmetics be managed through changes to poisons scheduling.

Lead acetate should not be allowed for dyeing hairs, eyelashes, eyebrows or moustaches (hair on the scalp and hair on other parts of the body).

Bismuth citrate (CAS No. 813-93-4) is already being used as an alternative for lead acetate in hair dye products available overseas.

Assessment of lead acetates is considered sufficient provided that risk management recommendations are implemented and all requirements are met under workplace health and safety and poisons legislation as adopted by the relevant state or territory.

Advice for consumers

Products containing the chemical should be used according to label instructions.

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