Australian Government
Department of Health
Australian Industrial Chemicals Introduction Scheme

Phenyl propanaldehydes

Evaluation statement

30 June 2022

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AICIS evaluation statement

Subject of the evaluation

Phenyl propanaldehydes

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Reason for the evaluation

Evaluation Selection Analysis indicated a potential risk to the environment.

Parameters of evaluation

This evaluation considers the environmental risks associated with industrial uses of 12 chemical substances commonly used as fragrance ingredients or intermediates. These chemicals have been assessed for their risks to the environment according to the following parameters:

- Default domestic introduction volumes of 100 tonnes (t) per annum.
- Industrial uses listed in the ‘Summary of Use’ section.
- Expected emission into sewage treatment plants (STPs) following normal consumer and commercial use.

Summary of evaluation

Summary of introduction, use and end use

Chemicals in this group evaluation are used as fragrance ingredients in industrial products. They are also used as reaction intermediates in the preparation of other chemicals. Specific Australian use volumes are unavailable although public information indicates that some of the substances are available for use within Australia.

Phenyl propanaldehydes may be used in the following products according to available domestic and international use data:

- Air freshener products
- Cleaning and furniture care products
- Laundry and dishwashing products
- Personal care products.

Global use volumes for individuals within the group range from relatively low levels through to volumes exceeding thousands of tonnes per annum.

Environment

Summary of environmental hazard characteristics

According to domestic environmental hazard thresholds and based on the available data these chemicals are:

- Not Persistent (not P)
- Not Bioaccumulative (not B)
- Not Toxic (not T).

Environmental hazard classification

Chemicals in this group satisfy the criteria for classification according to the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) for environmental hazards as follows. This does not consider classification of physical hazards and health hazards.

Environmental Hazard	Hazard Category	Hazard Statement
Acute Aquatic	Acute aq. – Cat. 2	H401: Toxic to aquatic life

Summary of environmental risk

Phenyl propanaldehydes are fragrance chemicals expected to have use in consumer and industrial products in Australia. They are also used as intermediates in the manufacture of other chemicals. Phenyl propanaldehydes may be released to the air and aquatic compartments of the environment during use and disposal by diffuse atmospheric releases or in STP effluent.

These chemicals are not persistent, not bioaccumulative, and not toxic to aquatic organisms. These chemicals are expected to undergo rapid abiotic and biotic degradation in the air and aquatic compartments. Exposure modelling based on default introduction volumes indicate likely concentrations of these chemicals in Australian rivers to be below the level of concern (RQ < 1). Therefore, the industrial use of these chemicals in Australia is unlikely to pose a significant risk to the environment.

Conclusions

The conclusions of this evaluation are based on the information described in this Evaluation Statement.

The Executive Director is satisfied that the identified environment risks can be managed within existing risk management frameworks. This is provided that all requirements are met under environmental, workplace health and safety and poisons legislation as adopted by the relevant state or territory.

Note: Obligations to report additional information about hazards under *Section 100 of the Industrial Chemicals Act 2019* apply.

Supporting information

Grouping rationale

This evaluation considers the environmental risks associated with the industrial uses of 12 chemicals used as fragrances or chemical intermediates. Chemicals in this group all share a common structural motif, 3-phenyl propanaldehyde. They have been evaluated as a group as they share common use patterns, hazard characteristics and a common toxic mode of action mediated by the reactive aldehyde functional group.

Fragrance chemicals are used as ingredients in a range of consumer products. Their use in these products is expected to result in the release of these chemicals to wastewater or air as a normal part of their use pattern.

The Evaluation Selection Analysis indicated potential toxicity to aquatic organisms and a risk to the environment. This evaluation includes further refinement of the risk characteristics of these chemicals.

Chemical identity

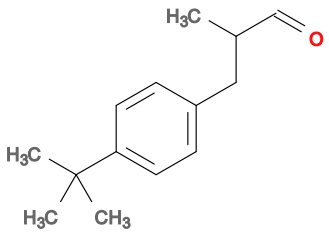
Chemicals in this group are structurally related derivatives of 3-phenylpropanal and are used as fragrances. alpha.,.alpha.,3-Trimethyl-benzenepropanal (majantal) also functions as a starting material in the preparation of the fragrance majantol (CAS No. 103694-68-4) (Walter Kuhn et al. 2003) and alpha-methyl-benzenepropanal is used primarily as an intermediate but may be present in essential oils (Al-azem et al. 2019).

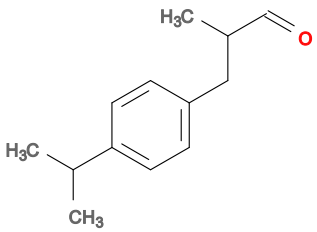
The substances have a common 3-phenylpropanal structural motif which differ in the substituents on the phenyl ring and propyl chain. The phenyl ring may carry a C1-C4 alkyl substituent in either the ortho-, meta- or para-position, whereas the propanal alkyl chain may have one or 2 methyl groups on the α- or β-carbon relative to the aldehyde.

The mono-methylpropanal derivatives have 2 stereoisomers due to the presence of a stereocentre on the propanal alkyl chain. These chemicals are commercially available as racemic mixtures. The synthesis and isolation of the pure enantiomers of the α-methylpropanal derivatives is possible but not industrially practical, as α-chiral aldehydes easily racemise via keto-enol tautomerism (Bernauer et al. 2017).

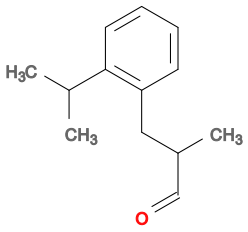
The compounds in this evaluation are prepared along several possible synthetic routes (Chapuis and Jacoby 2001; Möhle et al. 2018; Rowe 2005; Schnuch et al. 2017). alpha.-Methyl-4-(1-methylethyl)-benzenepropanal (cyclamen aldehyde) and 2(or 4)-ethyl-.alpha.,.alpha.-dimethyl-benzenepropanal (floralozone) are prepared by the Friedel-Crafts alkylation of isopropylbenzene (CAS No. 98-82-8) or ethylbenzene (CAS No. 100-41-4) to install the propanal chain (ScenTree SAS 2022a; 2022b). This protocol leads to the generation of ortho- and para- isomers in the technical product and both fragrances are expected to be used in industrial products as mixtures. alpha.-Methyl-2-(1-methylethyl)-benzenepropanal (ortho-cyclamen aldehyde) is expected to occur as a minor constituent (approximately 10%) of technical preparations of cyclamen aldehyde and floralozone is a mixture of the structural isomers represented by CAS Nos. 67634-14-4 and 67634-15-5 that are also included in this evaluation.

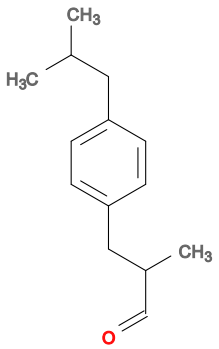
The remaining α-methylpropanal derivatives are prepared by aldol condensation of the corresponding alkylbenzaldehyde with propanal (CAS No. 123-38-6), followed by hydrogenation of the unsaturated aldehyde. Manjantal and alpha.,.alpha.-dimethyl-benzenepropanal (normajantal) are prepared by the reaction of a benzyl chloride (CAS No. 100-44-7) or 3-methylbenzyl chloride (CAS No. 620-19-9) with isobutyraldehyde (CAS No. 78-84-2). 4-(1,1-Dimethylethyl)-benzenepropanal (bourgeonal) is prepared by the aldol condensation of 4-tert-butylbenzaldehyde (CAS No. 939-97-9) with acetaldehyde (CAS No. 75-07-0) followed by hydrogenation (Rowe 2005):

CAS No.	80-54-6
Chemical name	benzenepropanal, 4-(1,1-dimethylethyl)-.alpha.-methyl-
Synonyms	lilial lysmeral .alpha.-methyl-.beta.-(p-tert-butylphenyl)propionaldehyde 2-methyl-3-(p-isopropylphenyl)propionaldehyde p-tert-butyl-.alpha.-methylhydrocinnamic aldehyde
Structural formula	
Molecular formula	$C_{14}H_{20}O$
Molecular weight (g/mol)	204.31
SMILES	O=CC(C)CC1=CC=C(C=C1)C(C)(C)C
Chemical description	-

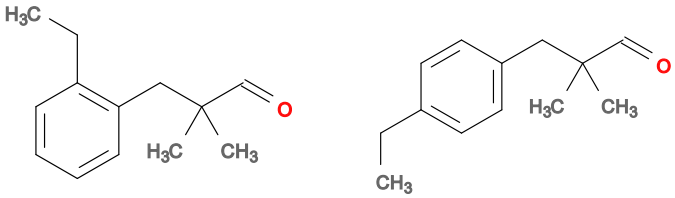
CAS No.	103-95-7
Chemical name	benzenepropanal, .alpha.-methyl-4-(1-methylethyl)-
Synonyms	cyclamen aldehyde .alpha.-methyl-4-(1-methylethyl)benzenepropanal 2-methyl-3-(4-isopropylphenyl)propionaldehyde hydrocinnamaldehyde, p-isopropyl-.alpha.-methyl
Structural formula	

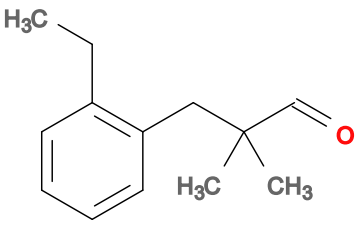
Molecular formula	$C_{13}H_{18}O$
Molecular weight (g/mol)	190.28
SMILES	O=CC(C)CC1=CC=C(C=C1)C(C)C
Chemical description	-

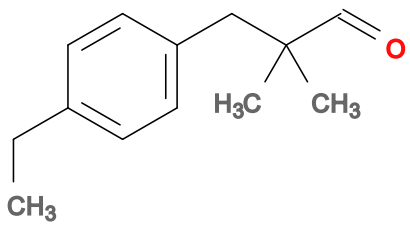
CAS No.	6502-20-1
Chemical name	benzenepropanal, .alpha.-methyl-2-(1-methylethyl)-
Synonyms	ortho-cyclamen aldehyde .alpha.-methyl-2-(1-methylethyl)benzenepropanal
Structural formula	
Molecular formula	$C_{13}H_{18}O$
Molecular weight (g/mol)	190.28
SMILES	O=CC(C)CC=1C=CC=CC1C(C)C
Chemical description	-

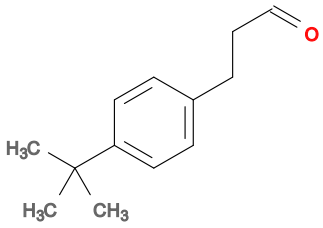
CAS No.	6658-48-6
Chemical name	benzenepropanal, .alpha.-methyl-4-(2-methylpropyl)-
Synonyms	silvial isobutyl lilial hydrocinnamaldehyde, p-isobutyl-.alpha.-methyl
Structural formula	
Molecular formula	$C_{14}H_{20}O$

Molecular weight (g/mol)	204.31
SMILES	O=CC(C)CC1=CC=C(C=C1)CC(C)C
Chemical description	-

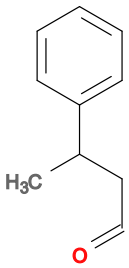
CAS No.	93963-78-1
Chemical name	benzenepropanal, 2(or 4)-ethyl-.alpha.,.alpha.-dimethyl-
Synonyms	florazon floralozone
Structural formula	
Molecular formula	$C_{13}H_{18}O$
Molecular weight (g/mol)	190.28
SMILES	CCc1ccccc1CC(C)(C)C=O
Chemical description	-

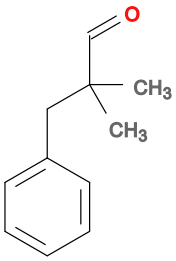
CAS No.	67634-14-4
Chemical name	benzenepropanal, 2-ethyl-.alpha.,.alpha.-dimethyl-
Synonyms	3-(2-ethylphenyl)-2,2-dimethylpropanal
Structural formula	
Molecular formula	$C_{13}H_{18}O$
Molecular weight (g/mol)	190.28
SMILES	O=CC(C)(C)CC=1C=CC=CC1CC
Chemical description	-

CAS No.	67634-15-5
Chemical name	benzenepropanal, 4-ethyl-.alpha.,.alpha.-dimethyl-
Synonyms	3-(4-ethylphenyl)-2,2-dimethylpropanal
Structural formula	
Molecular formula	$C_{13}H_{18}O$
Molecular weight (g/mol)	190.28
SMILES	O=CC(C)(C)CC1=CC=C(C=C1)CC
Chemical description	-

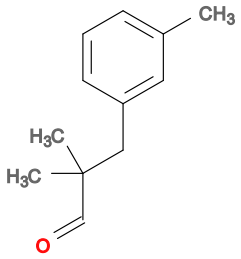
CAS No.	18127-01-0
Chemical name	benzenepropanal, 4-(1,1-dimethylethyl)-
Synonyms	bourgeonal p-tert-butylhydrocinnamic aldehyde
Structural formula	
Molecular formula	$C_{13}H_{18}O$
Molecular weight (g/mol)	190.28
SMILES	O=CCCC1=CC=C(C=C1)C(C)(C)C
Chemical description	-

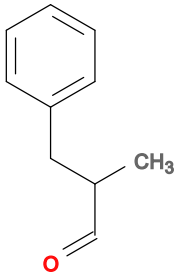
CAS No.	16251-77-7
Chemical name	benzenepropanal, .beta.-methyl-
Synonyms	trifernal 3-methyl-3-phenylpropanal 3-phenylbutanal

Structural formula	
Molecular formula	$C_{10}H_{12}O$
Molecular weight (g/mol)	148.20
SMILES	O=CCC(C=1C=CC=CC1)C
Chemical description	-

CAS No.	1009-62-7
Chemical name	benzenepropanal, .alpha.,.alpha.-dimethyl-
Synonyms	normajantal 2,2-dimethyl-3-phenyl propionaldehyde
Structural formula	
Molecular formula	$C_{11}H_{14}O$
Molecular weight (g/mol)	162.23
SMILES	O=CC(C)(C)CC=1C=CC=CC1
Chemical description	-

CAS No.	107737-97-3
Chemical name	benzenepropanal, .alpha.,.alpha.,3-trimethyl-
Synonyms	majantal

Structural formula	
Molecular formula	$C_{12}H_{16}O$
Molecular weight (g/mol)	176.25
SMILES	O=CC(C)(C)CC=1C=CC=C(C1)C
Chemical description	-

CAS No.	5445-77-2
Chemical name	benzenepropanal, .alpha.-methyl-
Synonyms	2-benzylpropanal methylhydrocinnamaldehyde
Structural formula	
Molecular formula	$C_{10}H_{12}O$
Molecular weight (g/mol)	148.20
SMILES	O=CC(C)CC=1C=CC=CC1
Chemical description	-

Relevant physical and chemical properties

Limited measured chemical property data are available for all substances in this group. Measured physical and chemical property data for 6 of the 12 substances were available from dossiers submitted under the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) (REACHa; REACHb; REACHc; REACHd; REACHe).

The physical and chemical properties for 3 substances in the group, covering the group molecular weight range, are reported below. These are expected to represent the range of properties of the overall group of 12 substances given their structural similarity. The Henry's Law constants below were calculated in EPI Suite (US EPA 2017):

Chemical	trifernal	majantal	lilial
Physical form	liquid	liquid	liquid
Melting point	-20.1°C (exp.)	2.7°C (exp.)	-20°C (exp.)
Boiling point	228°C (exp.)	236.5°C (exp.)	279°C (exp.)
Vapour pressure	5.2 Pa at 20°C (exp.)	1.17 Pa (exp.)	0.25 Pa (exp.)
Water solubility	2000 mg/L (exp.)	60 mg/L (exp.)	33 mg/L (exp.)
Henry's law constant	0.2 Pa·m^3/mol (calc.)	2.1 Pa·m^3/mol (calc.)	2.5 Pa·m^3/mol (calc.)
Ionisable in the environment?	no	no	no
pKa	no ionisable groups	no ionisable groups	no ionisable groups
log K_{ow}	1.9 (exp.)	3 (exp.)	4.2 (exp.)

Chemicals in this group are all neutral organic molecules that are moderately soluble in water, except for trifernal which is readily soluble. They are all liquids and are moderately volatile to volatile at standard room temperature and pressure. The calculated Henry's law constant for all chemicals indicate they are moderately volatile from water.

The members of the group with alkyl chains on the phenyl ring are lipophilic based on the reported logarithmic octanol-water partition coefficients (log K_{ow}). The remaining chemicals have a low to moderate lipophilicity.

Introduction and use

Australia

No specific Australian use, import, or manufacturing information has been identified.

Based on information in the public domain, several of these substances are available for use in Australia as fragrance ingredients (Australian Botanical Products Accessed 2021).

International

Available information indicates that phenyl propanaldehydes are used as fragrance ingredients in a range of household and personal care products worldwide (Zarogianni et al. 2017; Zviely 2012). Some members of the group are also used as intermediates in the preparation of other chemicals and as flavouring chemicals. Some are used at high volumes,

whereas others have lower or indeterminate usage levels, or occur primarily as reaction intermediates.

Several chemicals in this group (trifernal, cyclamen aldehyde, lilial, bourgeonal, silvial, floralozone) are listed on the International Fragrance Association (IFRA) Transparency List, which identifies chemicals used as fragrances by member companies (IFRA 2016). In addition, several are listed on the European Union (EU) Cosmetic Ingredients and Substances Database (CosIng) (trifernal, cyclamen aldehyde, silvial, lilial) (European Commission 2020). Others are reported or advertised elsewhere as fragrance ingredients: majantal (Dilk and Surburg 2005; Yokowo et al. 1981), cyclamen aldehyde (Valentine and Brandman 1983) and floralozone (The Good Scents Company 2022).

Lilial is listed on the Organisation for Economic Co-operation and Development (OECD) High Production Volume (HPV) list which indicates that more than 1000 tonnes of the chemical are manufactured per year in at least one member country (OECD 2020). Trifernal has reported global use volumes of 10 to 100 tonnes per year (Api et al. 2020).

Six chemicals in this group are registered under the REACH legislation in the EU. The total registered use volumes for trifernal, bourgeonal and silvial are ≥ 10 to < 100 tonnes per annum for each; for cyclamen aldehyde it is ≥ 100 to < 1 000 tonnes per annum; for lilial it is ≥ 1 000 to < 10 000 tonnes per annum (ECHAa; ECHAb; ECHAc; ECHAd; ECHAe). In the United States of America (USA), some chemicals in this group have maximum use and production volumes reported according to the Chemical Data Rule (under the Toxic Substances Control Act) (US EPA 2016). These volumes are: lilial at up to 4532 tonnes per year; trifernal, cyclamen aldehyde, bourgeonal, silvial at up to 453.2 tonnes per year; and normajantal at up to 12.15 tonnes per year. Lilial is listed as a HPV chemical in the USA (US EPA 2020).

Bourgeonal is listed on the Canadian Domestic Substances List (DSL) as an existing substance in commerce in Canada, at a usage volume of up to 0.76 tonnes per year (Government of Canada 2021).

In Japan, lilial was manufactured or imported in volumes up to 542 tonnes per year between the years of 2012–2019 (NITE 2022).

The chemical 2-benzylpropanal (CAS No. 5445-77-2) is a component in some essential oils (Al-azem et al. 2019).

Existing Australian regulatory controls

Environment

The use of chemicals in this group is not subject to any specific national environmental regulations.

International regulatory status

United Nations

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 & FAO 1998).

European Union

Lilial is identified as a Substance of Very High Concern (SVHC) due to its potential reproductive toxicity. The European Chemicals Agency (ECHA) has recommended that lilial is added to Annex XIV (the Authorisation list), which would require industry to seek authorisation for use of lilial in certain products and use types (ECHA 2021).

The SVHC Annex XV report on lilial referenced a scientific study that proposed a possible alternative to lilial for use in cosmetic products (ECHA 2021). The study indicated that 3-(4-isobutyl-2-methylphenyl)propanal retains fragrance qualities without the reproductive toxicity hazard (Laue et al. 2017).

Lilial has been prohibited from use in cosmetics in the EU from 1 March 2022 on account of its classification as toxic for reproduction (European Commission 2021). Bourgeonal is limited to a concentration of 0.6% in cosmetic products (European Commission 2020).

Other

The use of lilial in some cosmetic products has been restricted by IFRA. The chemical may not be used by IFRA members for any finished product application in lipsticks and oral care products. Lilial, as well as trifernal, cyclamen aldehyde, silvial and bourgeonal may only be used in limited concentrations in certain cosmetic types due to dermal sensitisation and systemic toxicity concerns (IFRA 2022).

Environmental exposure

Available international use data indicate chemicals in this group are common components of a variety of consumer and industrial products used in household and commercial settings such as personal care products, cleaning agents and air freshener products. The formulation of these products in the Australian market is not expected to differ significantly from identified international use patterns.

Fragrance ingredients are common components of many consumer and industrial products such as cosmetics, personal hygiene products, air deodorisers and household and industrial cleaning agents. These products are typically released to wastewater as a normal part of their use. Treatment of this wastewater in sewage treatment plants will remove some portion of these chemicals from influents to the STP. Depending on the efficiency of various degradation and partitioning processes in the STP, these chemicals can be emitted to the air compartment, to rivers or oceans in treated effluent, or to soil by application of biosolids to agricultural land. Emission of phenyl propanaldehydes to air and to surface waters is the most relevant in this evaluation.

Chemicals in this group are also used as intermediates in the manufacture of other chemicals. Manufacturing activity may lead to localised release of these chemicals to soil and air, as well as release of small amounts to STP through the disposal of aqueous residues or during clean up of plant and equipment.

Environmental fate

Partitioning

Chemicals in this group are expected to remain in water and soil when released to the environment.

The properties of these chemicals in this group range from moderately volatile and lipophillic (lilial, v.p. 0.25 Pa at 20°C, log K_{ow} = 4.2) to volatile with a low lipophilicity (trifernal, v.p. 5.24 Pa at 20°C, log K_{ow} = 1.9). Based on the calculated Henry's Law constants, these chemicals in this group are moderately volatile from water and moist soil. Calculated logarithmic organic carbon soil adsorption coefficients (log K_{oc}) indicate medium to very high mobility in soil for chemicals included in this group (log K_{oc} 1.5–2.6 L/kg).

Calculations with a standard multimedia partitioning (fugacity) model assuming equal and continuous distributions to air, water and soil compartments (Level III approach) (US EPA 2020) predict that these chemicals will mainly partition to the soil (69–80%) and water compartment (18–29%). However, assuming sole release to the water compartment based on their use patterns and disposal to STPs, these chemicals will predominantly partition to water (97.6%–99.3%).

Degradation

Chemicals in this group are expected to be degraded by natural processes.

Phenyl propanaldehydes rapidly degrade in the atmosphere. Trifernal and lilial are predicted to undergo rapid photo-oxidation by hydroxyl radicals in the atmosphere (reaction half lives = 0.315 and 0.324 days respectively) (US EPA 2017). These predicted values are expected to be representative for the members of this group.

Experimental data derived according to standard guidelines (OECD 1992) indicate that all 6 REACH registered chemicals are readily biodegradable in water (REACHa; REACHb; REACHc; REACHd; REACHe). This is expected to be the case for all chemicals in the group. Bourgeonal, silvial and lilal have been found to be readily biodegradable in studies conducted in accordance with OECD Test Guideline (TG) 301F, undergoing 65%, 75% and 84% degradation respectively after 28 days. Trifernal was also readily biodegradable with 97% degradation after 28 days with the 10 day window criterion met in an OECD TG 301A test. Cyclamen aldehyde underwent 66% degradation after 28 days in an OECD TG 301B test.

Bioaccumulation

Chemicals in this group have a low potential to bioaccumulate.

No bioaccumulation study data are available for chemicals in this group. In the absence of experimental bioaccumulation data, log K_{ow} values can be used to provide an indication of bioaccumulation potential in aquatic organisms. The experimental log K_{ow} value for lilial is equal to the domestic categorisation threshold for bioaccumulation (log K_{ow} = 4.2), which would indicate the chemical has potential for bioaccumulation. Trifernal, cyclamen aldehyde, bourgeonal and silvial have low experimental log K_{ow} values indicating they have a low potential for bioaccumulation.

Chemicals in this group are expected to undergo metabolism in fish which can reduce the potential for bioconcentration. Calculations using a standard quantitative structure bioconcentration relationship (QSBR) indicate that the bioconcentration factor (BCF) for lilial is 1607 L/kg wet-weight for the upper trophic level in fish (US EPA 2017). After including estimated biotransformation half lives, the BCF value for lilial is 682.7 L/kg wet-weight. This value is below the domestic categorisation threshold of a bioaccumulation hazard for aquatic life (2000 L/kg).

Environmental transport

Chemicals in this group are not expected to undergo long range transport.

Phenyl propanaldehydes are readily biodegradable in water and are rapidly degraded in the atmosphere.

Although bourgeonal has been detected in the Arctic region (Ny-Ålesund, Svalbard, Norway), this detection was attributed to local anthropogenic inputs rather than long range transport (Vecchiato et al. 2018). Bourgeonal was not detected in Antarctic seawater (Terra Nova Bay) sampling (Vecchiato et al. 2017), and no other remote regional monitoring data for these chemicals in this group was found.

Predicted environmental concentration (PEC)

Predicted Environmental Concentrations (PECs) for chemicals in this group in inland surface waters range from 5.62 to 7.3 micrograms per litre (µg/L).

No Australian environmental monitoring data were identified for these chemicals. Therefore, standard exposure modelling for the release of chemicals to surface water from STPs was used to estimate concentrations of each chemical in river water receiving treated effluents (Struijs 1996). International monitoring data were available for the most frequently used members of this group, lilial and bourgeonal; however, the estimated values were preferred to account for possible use pattern differences.

Chemicals in this group are primarily used as flavours and fragrances and are expected to enter the environment from STP effluent. Based on standard models for partitioning and biodegradation of chemicals in STPs, 87 to 90% of chemicals in this group entering an STP are predicted to be removed from wastewater. The PECs for the riverine compartment are calculated to be between 5.62 and 7.3 µg/L for chemicals in this group after taking into account substantial removal from wastewater by sorption to sludge and biodegradation and considering the assumed maximum annual introduction volume of 100 tonnes for each chemical.

International monitoring data suggest that these concentrations may be overestimates. A monitoring study of common household fragrances at STPs in Germany found lilial in effluent water at concentrations ranging from 0.038–0.1 µg/L (Klaschka et al. 2013). Influent concentrations at one STP in this study averaged 0.8 µg/L and calculated removal efficiencies were 90% after secondary level of STP treatment (activated sludge). Another study in Belgrade measured lilial at 0.21 µg/L in wastewater discharged to rivers (Relić et al. 2017).

Bourgenal has been detected in the canal water in Venice at concentrations up to 0.107 µg/L (Vecchiato et al. 2016).

Environmental effects

Effects on Aquatic Life

Phenyl propanaldehydes have a non-specific reactive mode of toxic action which is mediated by a reactive aldehyde functional group. The toxic effect of aldehydes typically occurs through formation of Schiff bases or electrophilic addition to biomolecules and enzymes in cells. These interactions can impair normal cellular function potentially leading to cellular death (Dimitrov et al. 2004; LoPachin and Gavin 2014).

Experimental data is available for 6 out of 12 chemicals in the group. This information is considered sufficient to assess the aquatic toxicity for all members of the group. These chemicals all share a common chemical structure and a common toxic mode of action. They differ by varying degrees of alkyl substitution on the phenyl ring, a difference that will result in some members having a higher lipophilicity, which will make them more toxic to aquatic organisms. Data are available for the most lipophilic chemicals in the group (lilial and silvial), and all other members that are less lipophilic are expected to be less toxic to aquatic organisms. Therefore, it is appropriate to use the toxicity data for the most lipophilic chemicals to characterise the ecotoxicity of all chemicals in this group.

Acute toxicity

The following measured median lethal concentration (LC50) and median effective concentration (EC50) values for model organisms across 3 trophic levels exposed to a) lilial b) majantal c) silvial d) cyclamen aldehdyde e) bourgeonal or f) trifernal were obtained from dossiers submitted under REACH (REACH; REACHa; REACHb; REACHc; REACHd; REACHe).

Taxon	Endpoint	Method
Fish	a) 96 h LC50 = 2.04 mg/L	*Danio rerio* (zebrafish) mortality flow through OECD TG 203
	b) 96 h LC50 = 9 mg/L	*Danio rerio* (zebrafish) mortality static OECD TG 203
	c) 96 h LC50 = 11.3 mg/L	*Danio rerio* (zebrafish) mortality semi-static OECD TG 203
Invertebrate	a) 48 h EC50 = 10.7 mg/L	*Daphnia magna* (water flea) immobilisation static 79/831/EWG
	c) 48 h EC50 = 4.71 mg/L d) 48 h EC50 = 1.4 mg/L e) 48 h EC50 = 1.8 mg/L f) 48 h EC50 = 14 mg/L	*Daphnia magna* (water flea) immobilisation semi-static OECD TG 202
Algae	a) 72 h EC50 = 29.16 mg/L	*Desmodesmus subspicatus* (green algae) growth static DIN 38412
	b) 72 h EC50 = 8.7 mg/L c) 72 h EC50 = 1.44 mg/L d) 72 h EC50 = 4.3 mg/L f) 72 h EC50 = 12 mg/L	*Pseudokirchneriella subcapitata* (microalgae) growth static OECD TG 201

Chronic toxicity

The following measured no observed effect concentration (NOEC) and 10% effect concentration (EC10) for a) lilial c) silvial d) cyclamen aldehdyde and f) trifernal were obtained from databases submitted under REACH (REACHa; REACHb; REACHc).

Taxon	Endpoint	Method
Fish	a) 21 d NOEC ≥ 0.2 mg/L	*Pimephales promelas* (fathead minnow) reproduction flow-through OECD TG 229 no observable effects at test concentration
Algae	a) 72 h EC10 = 1.69 mg/L	*Desmodesmus subspicatus* (green algae) growth static DIN 38412
	c) 72 h EC10 = 1.16 mg/L d) 72 h EC10 = 2.6 mg/L f) 72 h EC10 = 9.5 mg/L	*Pseudokirchneriella subcapitata* (microalgae) growth static OECD TG 201

Effects on terrestrial life

Several chemicals in this group have been observed to adversely affect reproduction in rats. However this is unlikely to lead to quantifiable effects on mammals in the environment considering the required exposure route and levels.

Lilial, bourgeonal and cyclamen aldehyde have been observed to be reprotoxic to male rats exposed to low levels of these chemicals by oral gavage (lowest observed effect level (LOEL) = 25–50 mg/kg bw/d). The toxic effect has been proposed to arise from the formation of alkylbenzoic acid-CoA conjugates after biotransformation of these chemicals in vivo (Laue et al. 2017). However, oral exposure at the required concentrations is not considered to be relevant for the Australian environment due to the ready biodegradability of the substances and hence likely degradation prior to entering the aquatic or terrestrial food web.

Endocrine effects/activity

Lilial may have potential endocrine activity. However available evidence is inconclusive, and no link to adverse environmental outcomes has been established.

A 21 day toxicity study conducted in fathead minnow (*Pimephales promelas)* according to OECD TG 229 found a statistically significant increase in vitellogenin (VTG) levels in blood plasma for male fish at concentrations of 0.0625 mg/L and 0.2 mg/L. Female fish showed no difference in blood plasma levels compared to controls. No adverse treatment related effects on survival, appearance/behaviour, reproduction or morphological changes were observed and a dose dependent response was unable to be established (REACHc).

Predicted no-effect concentration (PNEC)

The PNEC for these chemicals in this group is 11.6 µg/L.

The lowest endpoints presented in this evaluation are considered representative of the ecotoxicity of all chemicals in this group. A PNEC of 11.6 µg/L was derived from the measured chronic algae endpoint for silvial (72 h EC10 = 1.16 mg/L) using an assessment

factor of 100. This assessment factor was selected as there is acute data available across 3 trophic levels and chronic data for one trophic level (EPHC 2009).

Categorisation of environmental hazard

The categorisation of the environmental hazards of the assessed chemicals according to domestic environmental hazard thresholds is presented below:

Persistence

Not Persistent (Not P). Based on results from standard tests that show ready biodegradability of 5 members of this group, all chemicals in this group are categorised as Not Persistent.

Bioaccumulation

Not Bioaccumulative (Not B). Based on low measured log K_{ow} values and low calculated BCF values, chemicals in this group are categorised as Not Bioaccumulative.

Toxicity

Not Toxic (Not T). Based on available ecotoxicity endpoints above domestic thresholds, chemicals in this group are categorised as Not Toxic.

Environmental risk characterisation

Based on the PEC and PNEC values determined above, the following Risk Quotients (RQ = PEC ÷ PNEC) have been calculated for release of chemicals in this group into the riverine aquatic compartment:

Chemical	PEC	PNEC	RQ
Silvial and its isomer (CAS No. 6658-48-6; 6502-20-1)	5.6 µg/L	11.6 µg/L	0.48
Lilial (CAS No. 80-54-6)	6.1 µg/L	11.6 µg/L	0.52
Majantal (CAS No. 107737-97-3) Normajantal (CAS No. 1009-62-7) Floralozone and constituent isomers (CAS Nos. 93963-78-1; 67634-15-5; 67634-14-4) Bourgeonal (CAS No. 18127-01-0)	6.7 µg/L	11.6 µg/L	0.57
Trifernal (CAS No. 16251-77-7) alpha-Methyl-benzenepropanal (CAS No. 5445-77-2) Cyclamen aldehyde (CAS No. 103-95-7)	7.3 µg/L	11.6 µg/L	0.63

An RQ of less than 1 indicates the chemical is not expected to pose a risk to the environment based on estimated emissions, as environmental concentrations are below levels likely to cause harmful effects.

The major use of these chemicals is as fragrance ingredients in industrial and consumer products. They are likely to enter the environment either directly to air or indirectly to surface waters in treated STP effluent. The environmental risks associated with these releases are likely to be mitigated by ready degradation through abiotic and biotic processes. Therefore, the industrial use of these chemicals in Australia are unlikely to pose a significant risk to the environment.

Uncertainty

This evaluation was conducted based on a set of information that may be incomplete or limited in scope. Some relatively common data limitations can be addressed through use of conservative assumptions (OECD 2019) or quantitative adjustments such as assessment factors (OECD 1995). Others must be addressed qualitatively, or on a case-by-case basis (OECD 2019).

The most consequential areas of uncertainty for this evaluation are:

- Available international monitoring data indicates that the environmental concentrations calculated in this evaluation may be overestimated. In some cases, the default use assumption is higher than the reported global use of some chemicals in this group.
- Experimental chronic toxicity studies of lilial on *Pimephales promelas* found a statistically significant increase in vitellogenin in blood plasma indicating potential for adverse endocrine activity. The increase in vitellogenin was not accompanied by other relevant markers such as morphological, behavioural or reproductive changes. Re-evaluation of the chemical may be required if additional data indicates a stronger endocrine activity that may pose a risk to environment.

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