



**Australian Government**

**Department of Health**

Australian Industrial Chemicals Introduction Scheme

# Linear alkylbenzene sulfonates

## Evaluation statement

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# AICIS evaluation statement

## Subject of the evaluation

Linear alkylbenzene sulfonates

## Chemicals in this evaluation

Name	CAS registry number
Benzenesulfonic acid, dodecyl-	27176-87-0
Benzenesulfonic acid, 4-dodecyl-	121-65-3
Benzenesulfonic acid, decyl-, sodium salt	1322-98-1
Benzenesulfonic acid, dodecyl-, ammonium salt	1331-61-9
Benzenesulfonic acid, 4-dodecyl-, sodium salt	2211-98-5
Benzenesulfonic acid, dodecyl-, compound with morpholine (1:1)	12068-08-5
Benzenesulfonic acid, p-dodecyl-, compound with cyclohexylamine (1:1)	14356-38-8
Benzenesulfonic acid, dodecyl-, sodium salt	25155-30-0
Benzenesulfonic acid, 2-decyl-, compd. with 4-decylbenzenesulfonate, sodium salt (1:4:4)	22967-67-5
Benzenesulfonic acid, dodecyl-, calcium salt	26264-06-2
Benzenesulfonic acid, dodecyl-, compound with 2-aminoethanol (1:1)	26836-07-7
Benzenesulfonic acid, dodecyl-, potassium salt	27177-77-1
Benzenesulfonic acid, dodecyl-, magnesium salt	27479-45-4
Benzenesulfonic acid, dodecyl-, compound with N,N-diethylethanamine (1:1)	29061-63-0
Benzenesulfonic acid, 4-dodecyl-, compound with 2-aminoethanol (1:1)	58089-99-9
Benzenesulfonic acid, mono-C10-16-alkyl derivatives, sodium salts	68081-81-2
Benzenesulfonic acid, dodecyldimethyl-, sodium salt	63428-97-7
Benzenesulfonic acid, dodecyl-, compound with 1,2-ethanediamine	67952-66-3
Benzenesulfonic acid, C10-13-alkyl derivatives, sodium salts	68411-30-3
Benzenesulfonic acid, dodecyl-, reaction products with ethanolamine	68442-72-8
Benzenesulfonic acid, C10-16-alkyl derivatives	68584-22-5
Benzenesulfonic acid, C10-16-alkyl derivatives, calcium salts	68584-23-6
Benzenesulfonic acid, C10-16-alkyl derivatives, potassium salts	68584-27-0
Benzenesulfonic acid, mono-C10-16-alkyl derivatives, ammonium salts	68910-31-6
Benzenesulfonic acid, mono-C10-16-alkyl derivatives, compounds with 2-aminoethanol	68910-32-7

Name	CAS registry number
Benzenesulfonic acid, C10-14-alkyl derivatives, sodium salts	69669-44-9
Benzenesulfonic acid, mono-C10-13-alkyl derivatives, ammonium salts	85480-54-2
Benzenesulfonic acid, mono-C10-13-alkyl derivatives, compounds with ethanolamine	85480-55-3
Benzenesulfonic acid, mono-C10-13-alkyl derivatives, potassium salts	85480-57-5
Benzenesulfonic acid, 4-C10-13-sec-alkyl derivatives	85536-14-7
Benzenesulfonic acid, 4-C10-14-alkyl derivatives, compounds with ethanolamine	85995-82-0
Benzenesulfonic acid, 2(or 4)-C10-14-alkyl derivatives, compounds with isopropanolamine	85995-83-1
Benzenesulfonic acid, 4-C10-14-alkyl derivatives, calcium salts	90194-26-6
Benzenesulfonic acid, 4-C10-14-alkyl derivatives, compounds with ethylenediamine (1:1)	90194-29-9
Benzenesulfonic acid, 4-C10-14-alkyl derivatives, compounds with ethylenediamine (2:1)	90194-30-2
Benzenesulfonic acid, 4-C10-14-alkyl derivatives, sodium salts	91696-66-1
Benzenesulfonic acid, mono-C10-13-sec-alkyl derivatives, calcium salts	97467-80-6
Benzenesulfonic acid, C10-14-alkyl derivatives	103818-94-6
Benzenesulfonic acid, 4-C10-13-sec-alkyl derivatives, sodium salts	127184-52-5

## Reason for the evaluation

The Evaluation Selection Analysis indicated a potential risk to the environment.

## Parameters of evaluation

This evaluation considers the environmental risks associated with the industrial uses of a group of linear alkylbenzene sulfonates (LASs) listed on the Australian Inventory of Industrial Chemicals (the Inventory). These chemicals have been assessed for their risks to the environment according to the following parameters:

- As commercially available mixtures, with production processes as indicated in the supporting information
- Expected release into sewage treatment plants (STPs) due to consumer and commercial use

These chemicals have been assessed as a group as they all have similar use patterns and are expected to produce alkylbenzene sulfonate anions in the environment. The environmental risks of the organic and inorganic cations of the chemicals in this evaluation are not considered in this evaluation, as they are either ubiquitous in the environment or have previously been assessed.

# Summary of evaluation

## Summary of introduction, use and end use

Linear alkylbenzene sulfonates (LASs) are common surfactants used in a variety of consumer and industrial cleaning products worldwide, with global use volumes in the millions of tonnes per year. Available domestic introduction volume data suggests that LASs may be used in the tens of thousands of tonnes per year in Australia.

LASs are used in the following products according to reported domestic and international use data:

- Laundry and dishwashing products
- Cleaning and furniture care products
- Automotive care products

## 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

These chemicals satisfy the criteria for classification according to the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) (UNECE, 2017) for environmental hazards as follows. This does not consider classification of physical hazards and health hazards.

Environmental Hazard	Hazard Category	Hazard Statement
Hazardous to the aquatic environment (acute / short-term)	Aquatic Acute 2	H401: Toxic to aquatic life
Hazardous to the aquatic environment (long term)	Aquatic Chronic 3	H412: Harmful to aquatic life with long-lasting effects

### Summary of environmental risk

LASs have cumulative domestic use volumes in the tens of thousands of tonnes per year. These chemicals are used widely as surfactants in consumer and commercial cleaning products and are released to wastewater as a normal part of their use pattern.

LASs are not toxic, have low bioaccumulation potential, and are not persistent.

Based on measured international concentrations in STP effluent, surface waters, sediments, and agricultural soils, LASs are expected to be present in Australian river, soil, and sediment compartments at concentrations below the level of concern.

## Conclusions

The conclusions of this evaluation are based on the information described in this statement. Obligations to report additional information about hazards under section 100 of the *Industrial Chemicals Act 2019* apply.

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.

# Supporting information

## Rationale

This evaluation considers environmental risks associated with the industrial uses of a group of linear alkylbenzene sulfonates (LASs), including sulfonic acids and sulfonate salts with organic or inorganic counterions. These substances are commercially produced using comparable manufacturing methods, and are used as surfactants in similar consumer and commercial products. After release to the environment they are all expected to dissociate to form their corresponding linear alkylbenzene sulfonate anions. Therefore, the evaluation of these substances has been conducted as a group as they are expected to have similar release patterns and behaviour in the environment.

LASs are used domestically in very high volumes (over 10 000 tonnes per year) and are found in a wide range of personal care and household products. Their use in these products has potential to result in environmental exposure through emission to sewers after their use, followed by release to the environment in the treated effluents and biosolids produced by STPs.

The Evaluation Selection Analysis (ESA) of these chemicals indicated a potential high concern for the environment based on very high domestic import and use volumes and subsequent release to environment. This evaluation will consider the scale of current emissions of LAS to the aquatic and terrestrial compartments and the risk to the environment from industrial use of these chemicals in Australia.

## Chemical identity

The alkylbenzene sulfonic acid structure consists of a phenyl ring substituted with a linear alkyl chain and a sulfonic acid group. These chemicals can have an alkyl chain length between 10 and 16 carbon atoms. The carbon chain distribution of the chemicals will vary depending on the method of production and the source of the precursor chemicals.

Commercial LASs are UVCBs (unknown or variable composition, complex reaction products or of biological origin) as they are a mixture of alkylbenzene sulfonate chemicals that vary in alkyl chain length and location of the phenyl group on the alkyl chain. In commercial LAS mixture, the distribution of alkyl chain lengths typically range between 10 and 14 carbons (C10–C14), with compounds with a chain length greater than 14 carbons contributing less than 1% to the total distribution. The average alkyl chain length for LAS mixtures can range from C11.6–C12.6, but is typically closer to C11.6–C11.8 in the US, Europe, Canada and Japan (HERA, 2013; OECD, 2005). Similar compositions of LAS chemicals are expected to be used in Australia.

LASs have structural variability resulting from their manufacture. Initial formation of linear alkylbenzenes (LAB) by alkylation of benzene with a linear alkane mixture (typically containing C10–C14 alkanes) results in a mixture of positional isomers, with the phenyl ring located on any non-terminal carbon location of the alkyl chain (OECD, 1995a; 2005). The alkylation method used can affect the distribution of isomers; for example, aluminium trioxide-mediated alkylation favours production of 2-phenylalkanes more than hydrogen fluoride-mediated alkylation (Cowan-Ellsberry, et al., 2014; Feijtel and van de Plassche, 1995). Subsequent sulfonation of LAB usually produces *ortho*- and *para*-substituted alkylbenzene sulfonic acids, with a steric preference for the *para*- position.

One of the chemicals in the group (CAS RN 63428-97-7) has additional methyl substitution on the phenyl ring, but this is not expected to have a significant impact on the environmental behaviour of the chemical.

The environmental risks of the organic and inorganic cations of the chemicals in this evaluation are not considered in this evaluation, as they are either ubiquitous in the environment or have previously been assessed.

Information for a representative of the chemicals in this group is tabulated below. The structure shown is only one of the possible structural isomers contained in the substance described by the Chemical Abstract Services Registry Number:

Chemical name	Benzenesulfonic acid, dodecyl-, sodium salt
CAS No.	25155-30-0
Synonyms	Sodium dodecylbenzenesulfonate Sodium laurylbenzenesulfonate
Representative structural formula	
Molecular formula	C <sub>18</sub> H <sub>29</sub> O <sub>3</sub> S.Na
Molecular weight (g/mol)	348.5 g/mol (C12)
SMILES	S(=O)(=O)([O-])c1ccc(C(C)CCCCCCCCC)cc1.[Na+]
Chemical description	This substance is a mixture of positional isomers of sodium dodecylbenzene sulfonate, with the phenyl ring located at any non-terminal carbon location of the alkyl chain.

## Relevant physical and chemical properties

Representative physical and chemical property data for this group of chemicals was retrieved from the OECD SIDS assessment of LAS (OECD, 2005). The logarithmic acid dissociation



constant (pKa) for a suitable analogue chemical was retrieved from the QSAR Toolbox database (LMC, 2020):

Physical form	Solid
Melting point	198.5°C (exp., C12 Na-LAS)
Boiling point	444°C (exp., C12 Na-LAS, decomposes)
Water solubility	0.1 g/L (exp., C12 Na-LAS)
Ionisable in the environment?	Yes
pKa	-1.34 (exp., read-across from <i>p</i> -toluenesulfonic acid)

*p*-Toluenesulfonic acid (CAS RN 104-15-4) was chosen as a suitable read-across chemical for the pKa as it has key structural similarities which are expected to result in similar ionisation behaviour. Linear alkylbenzene sulfonic acids and *p*-toluenesulfonic acid are each characterised by a phenyl group *para*-substituted with an alkyl group and a sulfonic acid moiety.

The chemicals in this group that are salts of linear alkylbenzene sulfonate are expected to have low volatility (de Oude, 1992). The water solubility value reported was determined at the critical micelle concentrations (CMCs), as is appropriate for surface-active substances. CMCs decrease with increasing alkyl chain lengths, so the water solubilities of the substances in this group are expected to be highest for C10 and lower for longer-chain LAS (Smith, 1997).

The octanol-water partition coefficient parameter ( $K_{ow}$ ) of the chemicals in this group is not considered to provide a reliable indicator of the partitioning behaviour of surface active substances in the environment (McWilliams and Payne, 2002), and therefore has not been reported.

## Introduction and use

### Australia

LASs have reported use as cleaning, washing, and surface active agents in consumer detergent products.

Several LASs were reported on the 2006 Australian High Volume Industrial Chemicals List (AHVICL) with reported uses as cleaning/washing agents and as surface active agents (NICNAS, 2006). Benzenesulfonic acid, dodecyl- (CAS RN 27176-87-0) had a reported introduction volume in the range of 10 000–99 999 tonnes per annum, while benzenesulfonic acid, C10–C16-alkyl derivatives (CAS RN 68584-22-5) had an introduction volume in the 1000–9999 tonnes per annum band.

In addition, benzenesulfonic acid, C10-C16 alkyl derivatives, calcium salts (CAS RN 68584-23-6), benzenesulfonic acid, dodecyl-, sodium salt (CAS RN 25155-30-0) and benzenesulfonic acid, C10-C14 alkyl derivatives, sodium salts (CAS RN 69669-44-9) all have reported domestic introduction volumes in the range of 100–999 tonnes.

## International

LASs are used globally as surfactants in the following products (Cowan-Ellsberry, et al., 2014; HERA, 2013; OECD, 2005):

- Laundry powders and liquids
- Dishwashing powders and liquids
- All purpose cleaners
- Car cleaning formulations

The concentration in products varies between countries and between specific uses, but is typically 1–25% for consumer products and 5–25% for industrial/professional products (OECD, 2005).

The global market for LASs was estimated to be 4 million tonnes in 2008, with North America estimated to consume 269 000 t/year (Cowan-Ellsberry, et al., 2014). In 2005, the European region had an estimated consumption of 430 000 tonnes, with 350 000 tonnes used in household applications (HERA, 2013).

Household detergents are estimated to account for 80–87% of global LAS consumption, with consumer laundry products the highest volume use (Cowan-Ellsberry, et al., 2014; HERA, 2013).

The LAS counterion is chosen to suit the desired end use. Sodium salts are most common for detergent applications and calcium salts are suitable for emulsifier use. Ammonium salts have use in dry-cleaning detergents and metal degreasing. Car shampoo, bubble baths and textile de-sizing are applications for triethanolammonium salts (H. A. Painter, 1992).

LASs have additional use in emulsion polymerisation, as wetting agents in various industrial applications, and as emulsifiers (Cowan-Ellsberry, et al., 2014).

The linear alkylbenzene sulfonic acids in this group are typically intermediates in the production of linear alkylbenzenesulfonates (LASs) (US EPA, 2004).

LASs are also used as emulsifiers for pesticide formulations (Cowan-Ellsberry, et al., 2014). Non-industrial use of LAS such as in agricultural products are not within the scope of this evaluation.

## Existing Australian regulatory controls

### Environment

A default water guideline value of 0.280 milligrams per litre (mg/L; 95% protection value) has been published for LAS in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2000). High reliability freshwater trigger values have been derived for LAS using the statistical distribution method.

# International regulatory status

## 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 & FAO, 1998).

## Environmental exposure

LASs are found in detergent products that are typically released to wastewater as part of their typical household or industrial use. Depending on the degradation and partitioning processes of chemicals in STPs, a fraction of the quantity of chemicals in wastewater entering STPs will be emitted to rivers or oceans in treated effluent, or to soil by application of biosolids to agricultural land. Emissions of LASs to environmental surface waters, sediment, and soil are considered as part of this evaluation.

A subset of uses may result in direct release to the environment, such as use in car washing products. In these uses, LASs may be emitted directly to the soil compartment, or to surface waters without STP treatment through stormwater drainage systems. However, these are expected to be a minor proportion of the overall use volume.

## Environmental fate

### Dissolution, speciation and partitioning

LASs are expected to dissociate into their respective sulfonate anions under environmental conditions. LASs are therefore not expected to volatilise significantly from water or moist soil.

LASs will rapidly and reversibly partition to sludge and organic carbon in sediments. C12 LAS has a measured sludge partitioning constant ( $K_p$ ) of = 3210 litres per kilogram (L/kg) (Temmink and Klapwijk, 2004).

### Degradation

LASs rapidly biodegrade under aerobic conditions in waters and soils.

LAS substances are readily biodegradable according to standard degradation tests. In four tests conducted according to OECD test guidelines 301A and 301B, 66.7–94% degradation of LAS chemical mixtures with average alkyl chain length of 11.6 carbons was observed. The 10-day window criterion was met in three of these tests (HERA, 2013; OECD, 2005).

Mineralisation of LASs has been observed in aerobic degradation tests conducted using environmental water samples. In a test using river water, C12 LAS mineralised to CO<sub>2</sub> with a half-life of 1.39–13.9 days (Larson and Payne, 1981). When natural sediments were added to form a water-sediment system, C12 LAS mineralised more rapidly, with a half-life of 0.73–2.67 days. In another test using marine water, primary degradation of LAS (alkyl chain length unspecified) was observed with a half-life of 4–7 days (Vives-Rego, et al., 2000).

Rapid LAS mineralisation has been observed in aerobic soils and aerobic STP sludge-soil mixtures. STP sludge samples were spiked with C12 LAS (sodium 4-(2-dodecyl)benzene

sulfonate) and mixed with soil samples to a series of total LAS concentrations (Gejlsbjerg, et al., 2001). In addition, soil samples were directly spiked with C12 LAS. Under aerobic conditions, mineralisation of C12 LAS was observed in all soil and sludge-soil tests with calculated mineralisation half-lives in the range of 7–9 days. An additional field monitoring study estimated that LAS chemical degrades in soils with a half-life of 7–22 days (Holt, et al., 1989).

Aerobic degradation of LASs is expected to primarily occur through the oxidation of a terminal carbon on the alkyl chain to form sulfophenyl carboxylates (SPCs), which then undergo further oxidation that reduces the length of the alkyl chain. The benzene phenyl ring is cleaved open and desulfonated before total mineralisation is achieved (Scott and Jones, 2000). Variation in the linear alkyl chain length is therefore not expected to affect the degradability of this class of chemicals.

Anaerobic degradation tests indicate that LASs do not degrade rapidly under anaerobic conditions (OECD, 2005).

## Bioaccumulation

The chemicals in this evaluation are not expected to bioaccumulate.

Bioconcentration tests conducted according to OECD TG 305 with discrete LAS chemicals with C10 to C13 alkyl chain lengths gave bioconcentration factors (BCF) in the range of 2–987 L/kg in fathead minnows (*Pimephales promelas*) (Tolls, et al., 1997). The highest measured BCF of 987 L/kg was for 2-phenyl C13 LAS, while C10-C12 LAS analogues returned BCF values lower than 211 L/kg. These values do not exceed the domestic threshold for bioaccumulation (BCF  $\geq$ 2000 L/kg) (EPHC, 2009).

The BCF of LAS homologues increases with length of the alkyl chain and decreases as the sulfophenyl group moves towards internal positions on the alkyl chain; the highest experimental BCF value (987 L/kg) was found for 2-phenyl C13 LAS (Tolls, et al., 1997). Commercial mixtures of LAS typically contain <1–10% of the C14 alkyl chain isomers and <1% of homologues with alkyl chain longer than C14 (OECD, 2005). As such, the average effective BCF of commercial mixtures is not expected to be higher than the domestic classification threshold (BCF  $\geq$ 2000) (EPHC, 2009).

Non-standard bioaccumulation tests on LAS chemicals found low bioaccumulation potential under environmental conditions in fish, mollusc, and invertebrate species. Measured BCF values were in the range of 9–119 L/kg after 32 days of an experimental stream bioconcentration study using C12 LAS (Versteeg and Rawlings, 2003).

## Environmental transport

LASs are not expected to undergo long-range transport due to the short degradation half-lives observed under environmental and screening test conditions.

## Predicted environmental concentration (PEC)

The total environmental concentration of LAS chemicals in Australian riverine surface waters is conservatively estimated at 0.273 mg/L. Concentrations in STP sludge-amended agricultural soils are estimated to be 1.35 milligrams per kilogram dry weight (mg/kg dw). Concentrations in freshwater river sediment are estimated to be 5.4 mg/kg dw.

No domestic environmental monitoring data for LASs were found. International environmental monitoring data are available for LAS concentrations in STP influents, effluents, surface waters, STP sludges and in sludge-amended soils.

Mass balance studies indicate that LASs are effectively removed in secondary STPs with activated sludge treatment. In one such STP 80–90% of LAS was degraded, 10–20% was adsorbed onto sludge and 1% was released to surface waters (HERA, 2013). In a Dutch monitoring study, primary treatment (sewage settling) alone was found to remove up to 40% LAS (Matthijs, et al., 1999).

Concentrations of LAS in wastewater before and after STP treatment have been studied in the UK (Holt, et al., 2003), the Netherlands (Matthijs, et al., 1999), and the US (McAvoy, et al., 1998; Sanderson, et al., 2006). Measured LAS concentrations in STP influents were in the range of 1.8–9.1 mg/L, with effluent concentrations varying according to the treatment process used. STP treatment employing activated sludge processes generally resulted in greater removal of LAS than trickling-filter type treatments. The average LAS concentration in trickling-filter STP effluent in the UK was 0.34 mg/L, with a maximum of 2.0 mg/L (Holt, et al., 2003). A similar range was found for US trickling-filter STPs (McAvoy, et al., 1998). Activated sludge STP effluent concentrations averaged 0.04 mg/L LAS in the UK, with a maximum of 0.273 mg/L (Holt, et al., 2003). Lower concentration ranges were found in the US and in the Netherlands (Matthijs, et al., 1999; McAvoy, et al., 1998).

In Australia, 80% of wastewater is subject to at least secondary treatment (BOM, 2021). An internal survey of Australian STPs indicated that only a minor proportion of wastewater is treated using trickling-filter processes; most Australian secondary treatment plants currently utilise activated sludge processes. Considering that river flows can consist entirely of STP effluent in some drier parts of Australia, a reasonable worst case environmental concentration for LASs in domestic rivers is therefore predicted to be 0.273 mg/L, based on the maximum reported LAS concentration in effluent after activated sludge treatment in international monitoring studies.

LAS concentrations in surface waters internationally are generally low. The average concentration in 54 river sampling sites over several UK catchment areas was 0.04 mg/L (Holt, et al., 2003). In Japan, measured surface water concentrations in four rivers were in the range of <0.004–0.081 mg/L (Miura, et al., 2008).

A survey of measured LAS concentrations in freshwater sediments found concentrations in the range of 0.5–5.3 mg/kg dw in sediments beneath STP outfalls (HERA, 2013). The maximum concentration found is taken as a conservative estimate of LAS concentrations in Australian freshwater sediments.

LASs removed by adsorption to sludge in STPs may be exposed to the environment by application to agricultural soil. In a survey of studies measuring LAS concentrations in European STPs, concentrations of LASs in aerobic sludges averaged 176 mg/kg dw with maximum concentrations below 1000 mg/kg dw (Schowanek, et al., 2007). Sludges from anaerobic digestion processes contained much higher concentrations of LAS, with an average of 5.56 g/kg dw and a maximum measured concentration of 30.2 g/kg dw. A field study tracking the concentration of LAS in agricultural soil when amended with sludge containing 3.7–5.1 g/kg dw LAS found that the initial soil LAS concentration of 27 mg/kg dw decreased rapidly to 1.4 mg/kg dw within 30 days (Mortensen, et al., 2001). A survey of 51 fields at 24 UK farms found that fields that had not received sludge in 4–6 months typically had LAS concentrations in soil <1 mg/kg (Holt, et al., 1989).

The calculated LAS concentration in Australian agricultural soil amended with biosolids is 1.35 mg/kg dw based on the mean measured European aerobic sludge concentration (176 mg/kg dw), typical biosolids application rates and a soil bulk density of 1300 kilograms per cubic metre (kg/m<sup>3</sup>) (EPHC, 2009; Langdon, et al., 2010). An equivalent calculation using the mean measured European anaerobic sludge concentration (5.56 g/kg dw) resulted in a soil concentration of 42.8 mg/kg dw.

## Environmental effects

### Effects on aquatic life

The chemicals in this group have the potential to cause toxic effects in aquatic organisms across multiple trophic levels. Aquatic toxicity of LASs are well studied and acute and chronic endpoints are available for many species across multiple trophic levels.

The toxicity of LASs increases with increasing alkyl chain length (Kimerle and Swisher, 1977; OECD, 2005). Degradants of LASs are significantly less toxic than the parent substances (Kimerle and Swisher, 1977; Oya and Hisano, 2010).

### Acute toxicity

The following measured median effective concentration (EC50) and median lethal concentration (LC50) values for freshwater model organisms across three trophic levels were taken from the OECD SIDS dossier (OECD, 2005). The lowest values from the dossier are tabulated:

Taxon	Endpoint	Method
Fish	96 h LC50 = 1.67 mg/L	<i>Lepomis macrochirus</i> (bluegill) C11.8 LAS Flow-through conditions Measured concentration
Invertebrates	48 h EC50 = 1.62 mg/L	<i>Daphnia magna</i> (water flea) Immobility OECD TG 202 Static conditions Nominal concentration
Algae	96 h EC50 = 29 mg/L	<i>Selenastrum capricornutum</i> (green algae) C11.8 LAS Growth rate ASTM 1984 Static conditions Measured concentration

## Chronic toxicity

The following measured no-observed-effect-concentration (NOEC) values for freshwater model organisms across three trophic levels were taken from the OECD SIDS dossier (OECD, 2005). The lowest values from the dossier are tabulated:

Taxon	Endpoint	Method
Fish	28 d NOEC = 1 mg/L	<i>Lepomis macrochirus</i> (bluegill) C11.6 LAS Juvenile growth Flow-through conditions Measured concentration
Invertebrates	21 d NOEC = 1.18mg/L	<i>Daphnia magna</i> (water flea) C11.8 LAS Reproduction Flow-through conditions Measured concentration
Algae	96 h NOEC = 0.4 mg/L	<i>Scenedesmus subspicatus</i> (green algae) C11.6 LAS Growth rate Static conditions Measured concentration

## Multi-species toxicity endpoints

High reliability default guideline values have been calculated for LAS concentrations in freshwater for the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2000). The calculation considered NOECs from five freshwater fish species, two species of freshwater crustaceans, two species of freshwater insects, six species of freshwater algae and one freshwater mesocosm study. The guideline value was calculated at 0.280 mg/L for 95% protection for C11.6 LAS.

Aquatic toxicity of LAS was also reviewed in the OECD SIAR (OECD, 2005). A freshwater HC5 (hazardous concentration for 5% of species) of 0.24 mg/L for C11.6 LAS was suggested based on data from six fish species, four aquatic invertebrates, six algae species, and two plant species.

## Effects on sediment dwelling life

LASs can cause toxic effects in sediment-dwelling organisms.

NOECs for four freshwater sediment-dwelling species were taken from the OECD SIDS dossier (OECD, 2005):

Taxon	Endpoint	Method
Mollusc	80 d NOEC = $\geq 200$ mg/kg dw	<i>Anodonta cygnea</i> (fresh water bivalve mollusc) Commercial LAS Mortality
	28 d NOEC = 81 mg/kg dw	<i>Lumbriculus variegatus</i> (blackworm) C11.4 LAS Survival, reproduction, and growth
Worm	3 d NOEC = 100 mg/kg dw	<i>Caenorhabditis elegans</i> (nematode) C11.4 LAS Survival, Fertility, Egg Production
Midge	24 d NOEC = 319 mg/kg dw	<i>Chironomus riparius</i> (midge) C11.8 LAS Emergence

## Effects on terrestrial life

Previous risk assessments of LASs on plants and soil invertebrates, soil microorganisms have been undertaken (Brandt, et al., 2003; Carlsen, et al., 2002; Elsgaard, et al., 2001; Jensen, et al., 2007; Mieure, et al., 1990; Mortensen, et al., 2001).

Chronic toxicity endpoints of LASs to 12 plants and 9 soil invertebrates were used to generate a species sensitivity distribution. A HC5 (95% protection) value of 35.3 mg/kg dw was calculated (Jensen, et al., 2007).

Toxicity to soil microorganisms was investigated in studies involving spiked agricultural soil and in-field sludge amended soils. In the short-term spiked agricultural soil study, EC10 values of LAS for a variety of endpoints ranged from  $<8$  mg/kg dw to  $>793$  mg/kg dw (Elsgaard, et al., 2001). An in-field investigation into the effects of LAS on soil microorganisms, using soil amended with sludge containing LAS concentrations up to 31.3 g/kg dw, found that LAS disturbance of certain microbial populations lasted only two months or less and was confined to soil within 30mm of the sludge (Brandt, et al., 2003).

## Endocrine activity

No signs of estrogenic effects for LAS or its SPC degradants were observed during recombinant yeast screening (Routledge and Sumpter, 1996).

## Predicted no-effect concentration (PNEC)

The PNEC of LASs for freshwater aquatic life under typical conditions is 0.280 mg/L in line with the 95% protection default guideline value that has been derived for Australia (ANZG, 2018).



The PNEC of LASs for terrestrial life is 35.3 mg/kg in line with the HC5 value derived by Jensen et al (Jensen, et al., 2007). While there is some indication of toxic effects to some soil microbiology populations, these effects are not expected to be persistent or widespread.

A sediment PNEC of 8.1 mg/kg dw was derived from the measured blackworm chronic toxicity endpoint (28 d NOEC = 81 mg/kg dw). An assessment factor of 10 was applied as chronic toxicity tests are available for three sediment species with different living and feeding conditions.

## 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 screening tests and experimental field measurements, the chemicals in this group are categorised as Not Persistent.

### Bioaccumulation

Not Bioaccumulative (Not B). Based on low measured bioconcentration factors (BCF) in fish, the chemicals in this group are categorised as Not Bioaccumulative.

### Toxicity

Not Toxic (Not T). Based on acute ecotoxicity values above 1 mg/L and chronic ecotoxicity values above 0.1 mg/L, the chemicals in this group are categorised as Not Toxic.

## Environmental risk characterisation

Based on the PEC and PNEC values determined above, Risk Quotients ( $RQ = PEC \div PNEC$ ) have been calculated for release of LASs to water, soil and sediment:

Compartment	PEC	PNEC	RQ
River	0.273 mg/L	0.28 mg/L	0.98
Soil	1.35 mg/kg dw	35.3 mg/kg dw	0.04
Sediment	5.3 mg/kg dw	8.1 mg/kg dw	0.65

For rivers, an RQ less than 1 indicates that LASs are not expected to pose a significant risk to the environment based on estimated emissions, as environmental concentrations are below levels likely to cause harmful effects.

For soils, an RQ less than 1 indicates that LASs are not expected to pose a significant risk to agricultural soils amended with aerobic STP sludge. There are some international data to indicate that the LAS concentration in soils amended with anaerobic STP sludge may exceed

the level of concern; however, the concentration of LASs is expected to rapidly decrease after sludge and so the duration of exposure at high concentrations is expected to be short.

For sediment, an RQ less than 1 indicates that LASs are not expected to pose a significant risk to the environment based on estimated emissions as the concentrations are below the levels likely to cause harmful effects.

The risk of LASs to the marine compartment has not been considered in this evaluation. However, emissions of LAS are unlikely to be a concern outside the immediate vicinity of the release point where discharge occurs into well-mixed marine waters.

## 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, 1995b). Others must be addressed qualitatively, or on a case-by-case basis (OECD, 2019).

The most consequential areas of uncertainty for this evaluation are:

- There are no domestic monitoring data for LASs in surface waters, soil or sediment. The risk profile of LASs may change should monitoring data become available to indicate that these chemicals are present in Australian environmental compartments at concentrations above the levels of concern.

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