



Australian Government

Department of Health and Aged Care

Australian Industrial Chemicals Introduction Scheme

Lauryl (dodecyl) sulfates

Evaluation statement

22 December 2022



Table of contents

Contents

AICIS evaluation statement.....	4
Subject of the evaluation	4
Chemicals in this evaluation	4
Reason for the evaluation.....	4
Parameters of evaluation.....	4
Summary of evaluation.....	5
Summary of introduction, use and end use	5
Environment.....	5
Conclusions.....	6
Supporting information	7
Rationale	7
Chemical identity	7
Relevant physical and chemical properties.....	9
Introduction and use	10
Australia.....	10
International.....	10
Existing Australian regulatory controls.....	11
Environment.....	11
International regulatory status	11
United Nations	11
OECD	12
European Union	12
United States of America	12

Japan.....	12
Environmental exposure.....	12
Environmental fate.....	13
Predicted environmental concentration (PEC).....	15
Environmental effects.....	17
Effects on Aquatic Life.....	17
Effects on sediment dwelling life.....	19
Endocrine effects/activity.....	19
Predicted no-effect concentration (PNEC).....	20
Categorisation of environmental hazard.....	20
Persistence.....	20
Bioaccumulation.....	20
Toxicity.....	20
Environmental risk characterisation.....	20
References.....	22

AICIS evaluation statement

Subject of the evaluation

Lauryl (dodecyl) sulfates

Chemicals in this evaluation

Name	CAS registry number
Sulfuric acid, monododecyl ester, sodium salt	151-21-3
Sulfuric acid, monododecyl ester, ammonium salt	2235-54-3
Sulfuric acid, monododecyl ester, magnesium salt	3097-08-3
Sulfuric acid, monododecyl ester, potassium salt	4706-78-9

Reason for the evaluation

Evaluation Selection Analysis indicated a potential environmental risk.

Parameters of evaluation

These chemicals are a group of monododecyl sulfate salts that are listed on the Australian Inventory of Industrial Chemicals (the Inventory). This evaluation considers the environmental risks associated with the industrial uses of these chemicals.

These chemicals have been assessed for their risks to the environment according to the following parameters:

- A combined domestic introduction volume of up to 2000 tonnes per year (t/year)
- Industrial uses listed in the 'Summary of Use' section
- Expected emission to sewage treatment plants (STPs) following consumer and commercial use.

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

Summary of evaluation

Summary of introduction, use and end use

Dodecyl sulfate salts are common surfactants used in a variety of consumer and industrial cleaning products worldwide, with global use volumes in the tens of thousands of tonnes per year. Available domestic introduction volume data suggests that dodecyl sulfate salts may be used in the thousands of tonnes per year in Australia.

The chemicals in this evaluation are used as surfactants in the following products according to domestic and international use data:

- Paint and coating products
- Plastic and polymer products
- Automotive care products
- Cleaning and furniture care products
- Laundry and dishwashing products
- Extractive products not covered by other end uses
- Personal care products not covered by other end uses.

Environment

Summary of environmental hazard characteristics

According to domestic environmental hazard thresholds and based on the available data the chemicals in this evaluation 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) for environmental hazards as follows. This evaluation does not consider classification of physical 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

Dodecyl sulfate salts have domestic use volumes in the 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.

Dodecyl sulfate salts are not persistent, have low bioaccumulation potential and are not toxic to aquatic life.

As the Risk Quotient (RQ) obtained is <1.0 , the industrial use of these chemicals in Australia are unlikely to pose a significant risk to the environment.

Conclusions

The evaluation conclusions 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

Rationale

This evaluation considers the environmental risks associated with the industrial uses of a group of dodecyl sulfate salts comprising a linear aliphatic hydrocarbon chain (C12) with a terminal sulfate anion, neutralised by an ammonium, sodium, potassium or magnesium cation. These chemicals are used industrially as anionic surfactants.

Sodium lauryl (dodecyl) sulfate (SLS) and ammonium dodecyl sulfate are chemicals used in high volumes in cleaning applications, personal care products and cosmetics. Their use in these products can result in environmental exposure through emission to sewers following their use, followed by release to the environment in the treated effluents produced by sewage treatment plants (STPs). The other chemicals in this group are expected to have similar uses, but at lower volumes.

The evaluation of these chemicals has been conducted as a group because they have known applications as surfactants and a common emission scenario.

Even though the physical-chemical behaviour of these chemicals may be influenced by different counterions, dissociation of the salts upon entry to wastewater yields a common dodecyl sulfate anion. Therefore, the distinction between chemicals does not affect the chemical reactivity and hazard classification for the purpose of this evaluation.

Chemical identity

Chemicals in this group are salts that share a common dodecyl sulfate anion, consisting of a linear aliphatic chain with 12 carbon atoms and terminating with a sulfate group. Chemicals in this group differ by the nature of the neutralising cation; sodium, potassium, magnesium or ammonium.

The CAS registration numbers (RN) describe single chemicals and are not UVCBs (unknown or variable composition, complex reaction products or of biological origin).

Physical form of SLS ranges from dry powders/solids with maximum concentrations of >90%, and liquids with concentrations of <1% or 30–60%. The physical form of ammonium dodecyl sulfate in the US is a liquid with a concentration of 1–30% (US EPA 2020).

Chemical name	sulfuric acid, monododecyl ester, sodium salt
CAS RN	151-21-3
Synonyms	sodium dodecyl sulfate (SDS) sodium lauryl sulfate (SLS) (INCI name) dodecyl hydrogen sulfate
Structural formula	
Molecular formula	$\text{NaC}_{12}\text{H}_{25}\text{SO}_4$
Molecular weight (g/mol)	288.38
SMILES	<chem>CCCCCCCCCCCCOS(=O)(=O)[O-].[Na+]</chem>
Chemical description	-

Chemical name	sulfuric acid, monododecyl ester, ammonium salt
CAS RN	2235-54-3
Synonyms	ammonium dodecyl sulfate ammonium lauryl sulfate (INCI name)
Molecular formula	$\text{NH}_4\text{C}_{12}\text{H}_{25}\text{SO}_4$
Molecular weight (g/mol)	283.43
SMILES	<chem>CCCCCCCCCCCCOS(=O)(=O)[O-].[NH4+]</chem>
Chemical description	-

Chemical name	sulfuric acid, monododecyl ester, magnesium salt
CAS RN	3097-08-3
Synonyms	magnesium dodecyl sulfate magnesium lauryl sulfate (INCI name)
Molecular formula	Mg(C ₁₂ H ₂₅ SO ₄) ₂
Molecular weight (g/mol)	555.09
SMILES	CCCCCCCCCCCCOS(=O)(=O)[O-].CCCCCCCCCCCCOS(=O)(=O)[O-].[Mg+2]
Chemical description	-

Chemical name	sulfuric acid, monododecyl ester, potassium salt
CAS RN	4706-78-9
Synonyms	potassium dodecyl sulfate potassium lauryl sulfate (INCI name)
Molecular formula	KC ₁₂ H ₂₅ SO ₄
Molecular weight (g/mol)	304.49
SMILES	CCCCCCCCCCCCOS(=O)(=O)[O-].[K+]
Chemical description	-

Relevant physical and chemical properties

Representative physical and chemical property data for SLS is reported. SLS is considered a suitable read-across analogue for determination of physical and chemical properties and other hazard characteristics of the chemicals in this group. Data were retrieved from the OECD Screening Information Data Set (SIDS) assessment of Alkyl Sulfates, Alkane Sulfonates and α -Olefin Sulfonates (OECD 2007), reference texts (Hodges et al. 2019; Mukerjee and Mysels 1971), and the dossier for SLS submitted under the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) legislation in the European Union (EU) (REACHa):

Physical form	Solid
Melting point	205°C (exp.)
Boiling point	216°C (exp.)
Water solubility	2367 mg/L at 25°C (exp.)
Ionisable in the environment?	Yes
pKa	1.31 at 20°C (exp.)
Log K _{ow}	1.92 (exp.)

The water solubility value reported is equal to the critical micelle concentration (CMC), as is appropriate for surface-active substances. The CMC of the other chemicals in this group ranges from 722 milligrams per litre (mg/L, 30°C, exp.) for magnesium dodecyl sulfate, to 1746 mg/L (25°C, exp.) for ammonium dodecyl sulfate, and 2375 mg/L (40°C, exp.) for potassium dodecyl sulfate (Mukerjee and Mysels 1971).

Chemicals in this group are expected to have very low vapour pressures because of their ionic nature (OECD 2007). Therefore, these surfactants are expected to be non-volatile and have negligible partitioning to air from water (Henry's Law constant).

The octanol-water partition coefficient parameter (K_{ow}) of surfactants is not considered to provide a reliable indicator of their partitioning behaviour in the environment (OECD 2007). The parameter can be measured for surfactants to an extent using the slow stirring method (OECD TG 123) but results should be applied with discretion (Hodges et al. 2019).

Introduction and use

Australia

There is currently no specific information about the introduction, use and end use of magnesium dodecyl sulfate or potassium dodecyl sulfate.

The chemicals SLS and ammonium dodecyl sulfate have reported domestic uses as surfactants with cleansing, emulsifying, foaming, wetting and dispersing properties in cosmetic, domestic and commercial applications (NICNAS 2013).

Based on information previously reported under NICNAS, the combined volume of use of SLS and ammonium dodecyl sulfate in Australia is in the range 1000–2000 t/year.

International

Available information indicates that SLS and ammonium dodecyl sulfate are high volume surfactants used in a range of cleaning, cosmetic and personal care products. They are also used as additives in the industrial manufacture of polymers and surface coatings (Singer and Tjeerdema 1993). Potassium dodecyl sulfate and magnesium dodecyl sulfate have evidence of use, but do not appear to be as widespread or high volume.

Dodecyl sulfates are popular due to their favourable surfactant properties (foaming, cleansing and rinsing) combined with relatively high water solubility. All the chemicals in this group are listed on the European Commission's cosmetic ingredients database (CosIng) as cleansing surfactants (EC 2022). Dodecyl sulfates are also used in commercial and industrial cleaners, personal care products, as industrial process aids in emulsion polymerization, as additives in plastic and paint production, and in surfactant-enhanced remediation of groundwater and soil (A.I.S.E. and Cefic 2002; Liu et al. 2021; NIEHS 2022b).

The chemical SLS is the highest volume chemical in this group and consumer products can contain high concentrations in either liquid or solid (granules or tablets) formulations (NIEHS 2022b). In a study of 703 personal care products and cosmetics it was found that 77% contained <1–10%, 20% contained 10–50% and 3% contained >50% of SLS (mostly shampoos) (Singer and Tjeerdema 1993).

The chemical SLS is a high production volume (HPV) chemical globally (OECD 2022), and is used in the EU in the range of 10 000–100 000 t/year (REACHa) and the United States of America (USA) in the range of 454–4536 t/year (US EPA 2020; US EPAb). In the Nordic countries, the average use volume from 2000–2019 was 2352 t/year (Nordic Council of Ministers 2022).

Ammonium dodecyl sulfate is a HPV chemical globally (OECD 2022). It is found in liquid formulations in concentrations up to 20% (NIEHS 2022a). In the USA it is listed as a HPV chemical (US EPAb), with an average use volume from 2016–2019 of 155 t/year (US EPA 2020). In the Nordic countries, the average use volume from 2002–2008 was 670 t/year (Nordic Council of Ministers 2022).

Potassium dodecyl sulfate and magnesium dodecyl sulfate are used in smaller quantities. The former is used in the EU in the range of 1–10 t/year (REACHb) and the latter has reported use in the Nordic countries in cleaning agents but no reported tonnage (Nordic Council of Ministers 2022).

SLS has non-industrial use in pesticides (NIEHS 2022b). The use of this chemical as a pesticide additive is beyond the parameters of this evaluation.

Existing Australian regulatory controls

Environment

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

International regulatory status

United Nations

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

OECD

The chemical SLS was sponsored by Germany under the Cooperative Chemicals Assessment Programme (CoCAP). The 4th SIDS Initial Meeting Assessment (SIAM 4) in 1996 agreed that the chemical presents a low potential for risk to the environment, and there is no priority to undertake further work (OECD 1996).

Three of the dodecyl sulfate salts (sodium, ammonium and potassium) were evaluated as part of the CoCAP evaluation of Alkyl Sulfates, Alkane Sulfonates and α -Olefin Sulfonates. In 2007, the SIAM 25 concluded that, while these chemicals have properties indicating a hazard for the environment (aquatic toxicity), they are of low priority for further work because of their rapid biodegradation under aerobic conditions and limited potential for bioaccumulation (OECD 2007).

European Union

European Commission (EC) directives dictate that the primary biodegradability resulting in loss of surface active properties of anionic surfactants, such as the chemicals in this evaluation, must be shown to be greater than 80% before they are placed on the market (EC 2004).

United States of America

The chemicals SLS, ammonium dodecyl sulfate and magnesium dodecyl sulfate are listed on the US EPA Safer Chemical Ingredients List. All chemicals have been verified to be of low concern based on experimental and modelled data. This list identifies chemicals deemed to be safer alternatives to other chemicals employed for the same functional use. The criteria for adding chemicals to the list covers a broad range of human health and environmental toxicological effects (US EPAa).

The chemicals in this group are approved for use in food contact surface sanitising solutions by the US EPA, with end-use concentrations not exceeding 350 parts per million (ppm) (US EPAc).

Japan

The chemicals SLS and ammonium dodecyl sulfate have been classified as Priority Assessment Chemical Substances (PACS) under Japan's Chemical Substances Control Law, indicating that these chemicals have been prioritised for assessment. An ecological effect has been identified and the chemicals are currently in Risk Assessment Phase 1-II for ecological effect (NITE 2022a; 2022b).

Environmental exposure

Chemicals in this group are used as surfactants in products that are typically released to wastewater as part of their typical household, commercial or industrial use. The prevalence of dodecyl sulfates in cleaning products such as shampoo and detergent results in high concentrations in greywater. Greywater collected from a student residence in India contained 15.0–35.9 mg/L of SLS (Ramprasad and Philip 2016).

Depending on the degradation and partitioning processes of chemicals in STPs, some proportion 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 the chemicals in this group to surface waters, sediment, and soil are considered as part of this evaluation.

Some uses may result in direct release to the environment, such as car washing and surfactant-enhanced remediation. For these uses the chemicals may be emitted directly to the soil or surface waters without STP treatment. Such direct emissions are expected to be a minor contribution compared to the widespread, continuous use of cleaning products that makes up most of the use volume.

Environmental fate

Chemicals in this group are expected to dissociate to a common dodecyl sulfate anion under environmental conditions in water, sediment and moist soil. The nature of the counterion is not expected to influence the hazard and exposure properties of these chemicals, and in the majority of cases available data from SLS is used to represent this group of chemicals.

Dissolution, speciation and partitioning

Chemicals in this group are expected to dissociate to a common dodecyl sulfate anion under environmental conditions. As ionic species, these chemicals are not expected to volatilise from water or moist soil.

SLS has a pKa of 1.31 (20°C, OECD TG 112) (REACHa), so the chemical is expected to exist predominately (>99%) in the anionic form.

Chemicals in this group will rapidly and reversibly partition to organic carbon in sludge and sediments. SLS has a measured sediment partitioning coefficient (Koc) of 316–446 (25°C) at environmental pH (7.6) (REACHa).

Degradation

In surface waters, soil and activated sludge, chemicals in this group rapidly and ultimately biodegrade. In sediment, chemicals in this group rapidly undergo primary degradation.

Primary biodegradation by bacteria begins with cleavage of the sulfate group to give 1-dodecanol and an inorganic sulfate salt. This results in loss of surfactant properties and mitigation of the hazards of concern (EC 2004; Ramprasad and Philip 2018). Bacteria can metabolise the alcohol as an energy source via oxidation to a carboxylic acid to produce a fatty acid, followed by β -oxidation and subsequent mineralisation (Könnecker et al. 2011; Painter 1992).

Degradation of SLS in the environment is mediated by bacteria present in the environment and STPs. The dodecyl sulfate anion is degraded with a half-life of 6 hours by *Pseudomonas aeruginosa* bacteria that are ubiquitous in water and soil in human inhabited environments (Crone et al. 2020; Marchesi et al. 1997; Paulo et al. 2013). In one experiment, 16 of the 29 bacterial species isolated from oil-contaminated alpine soils and glaciers were capable of degrading high concentrations of SLS (500–1000 mg/L) (Margesin and Schinner 1998).

Ultimate degradation of SLS has been quantified in standard tests, environmental river water, brackish water, soil and activated sludge from STPs.

The chemical (SLS) is readily biodegradable according to standard degradation tests. In 2 tests conducted according to OECD test guidelines 301B and 301D, 94–97% degradation was measured, and the 10-day window met (REACHa).

The chemical (SLS) underwent near-complete ultimate degradation (94.3% and 94.5%, mass balance normalised to 100%) in river water in 28 days under conditions equivalent to OECD TG 314D (REACHa). The chemical underwent 90% ultimate degradation in 2 days in brackish water (20°C, salinity 9.3–16.1‰ [parts per thousand]) collected from Chesapeake Bay, Maryland, USA (Cook and Goldman 1974).

The chemical (SLS) underwent ultimate degradation in clay-rich soil (25% in 7 days) that was inoculated with a mixed bacterial culture that was isolated from hydrocarbon-contaminated soil (Lima et al. 2011).

Chemicals that pass through STPs can adsorb to activated sludge and subsequently be applied to agricultural soil as fertiliser. Most of the chemical is removed during biological treatment at STPs according to standard tests. In a test that simulated chemical removal from biological treatment plants (OECD TG 302 A) the removal rate of a mixture of SLS and sodium tridecyl sulfate was $95 \pm 3\%$ DOC (dissolved organic carbon). In an Activated Sludge Simulation Test removal rates were 94.5% DOC (OECD 2007).

Primary degradation of SLS has been quantified in marine waters and water-sediment mixtures.

The chemical (SLS) underwent rapid primary degradation (>95%) in seawater from Spain (1 and 20 mg/L, 22–25°C) in 25–41 hours (Pérez-Carrera et al. 2010; Vives-Rego et al. 1987). SLS also underwent primary degradation with a half-life of 6 days (summer) to 19 days (winter) in Antarctic marine waters near the Rothera Research Station on Adelaide Island. The half-life is seasonal, despite water temperatures remaining constant (-1.8–0.65°C). It is thought that the influx of researchers in summer leads to greater waste emissions and enrichment of bacterial populations capable of biodegradation (George 2002).

The chemical (SLS) degrades in water-sediment mixtures under aerobic conditions. The chemical degraded by 40% in 24 hours in the presence of pond sediment (25°C, 1.2 grams per litre [g/L], 16% w/w organic matter) containing indigenous bacterial populations (Marshall et al. 2000).

Abiotic degradation is unlikely to be a major dissipation route. Dodecyl sulfates require hot acid-catalysed conditions to hydrolyse and will not do so under environmentally relevant conditions (Kosswig 2012; OECD 2007). SLS does not degrade by hydrolysis or photodegradation to an appreciable extent in the abiotic controls performed in aerobic biodegradation experiments under aqueous conditions (Margesin and Schinner 1998; Pérez-Carrera et al. 2010; Ramprasad and Philip 2018). Dodecyl sulfate salts are not volatile, so photodegradation in the atmosphere is not relevant.

Bioaccumulation

The chemicals in this group are not expected to bioaccumulate. Standard tests indicate that the log K_{OW} is below the domestic categorisation threshold for bioaccumulation hazards and

non-standard bioaccumulation tests found low bioaccumulation potential in fish, evidence of biotransformation, and rapid depuration.

The log K_{OW} of SLS (1.92) is below the domestic categorisation threshold for bioaccumulation hazards (log K_{OW} >4.2) (EPHC 2009; Hodges et al. 2019). However, because of the complex partitioning behaviour of surfactants, this value will not be relied on to assess the bioaccumulation hazard.

Non-standard tests in fish do not indicate a risk of bioconcentration. Carp (*Cyprinus carpio*) were exposed to 0.25 and 0.5 mg/L solutions of ^{35}S -labelled SLS for 72 hours, followed by a depuration period in freshwater of 120 hours. Despite such a short uptake period (3 days compared to the standard 28 days in OECD TG 305) equilibrium was reached in 24 hours. Whole body bioconcentration factor (BCF) values of 2 and 4 litre per kilogram (L/kg) wet weight (wwt) were determined. The highest BCF values reported based on radioactivity were in the hepatopancreas and gall bladder, at 20 and 50 L/kg wwt and 300 and 700 L/kg wwt. (Wakabayashi et al. 1978; 1980). These values are below domestic categorisation thresholds (BCF \geq 2000 L/kg) for bioaccumulation hazards (EPHC 2009).

The BCF was calculated from measured radioactivity, but analysis did not differentiate between the dodecyl sulfate anion and metabolites. Unidentified metabolites accounted for most of the radioactivity in the hepatopancreas and gall bladder, so the BCF value for dodecyl sulfate is likely an overestimation. Furthermore, concentration of metabolites in the gall bladder and hepatopancreas, both vital organs in the absorption and metabolism of lipids, may indicate recognition of dodecyl sulfate as a lipid-like food source. In contrast to biodegradation by bacteria, in which the sulfate group is cleaved, it appears that the sulfate group remains untouched in fish. In goldfish (*Carassius auratus*) the major metabolite was determined to be butyric acid-4-sulfate (Tovell et al. 1975).

The concentration of dodecyl sulfate and metabolites rapidly decreases during depuration periods. The ^{35}S radioactivity in carp reduced by 50% in 72 hours in the whole body, and 80% and 40% in 24 hours in the hepatopancreas and gall bladder, respectively (Wakabayashi et al. 1978; 1980). In goldfish the whole body radioactivity reduced by 38% in unfed fish and 68% in fed fish in 24 hours (Tovell et al. 1975).

Environmental transport

Chemicals in this group 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 dodecyl sulfates in Australian riverine surface waters is conservatively estimated to be 0.03 mg/L. Concentrations in marine waters are estimated to be 0.003 mg/L.

No domestic environmental monitoring data for dodecyl sulfates were found. International environmental monitoring data are available for dodecyl sulfate concentrations in STP influent and effluent, freshwater and marine sediments, and sewage sludge. While analytical methods detect the concentration of the dodecyl sulfate anion in environmental matrices, the reported concentration is invariably calibrated to the concentration of SLS.

Mass balance studies indicate that dodecyl sulfates are effectively removed in secondary STPs with activated sludge treatment. Primary removal rates range from 35–78% (Matthijs et al. 1999) and secondary removal rates range from 90–94% for trickling filter (Fendinger et al. 1992; McAvoy et al. 1998) and >99% for activated sludge (Matthijs et al. 1999).

Two studies from the USA measured the concentration of dodecyl sulfates in influent and effluent following trickling filter secondary treatment. Maximum concentrations measured in influent were 0.7 mg/L, while maximum concentrations in effluent were 0.1 mg/L (Fendinger et al. 1992; McAvoy et al. 1998). One of the studies identified drastic diurnal patterns in the concentration of this anion, and the time-weighted average concentration over a 24 hour period was 0.18 mg/L in influent and 0.03 mg/L in effluent (Fendinger et al. 1992).

These values are consistent with the concentrations of total C12–C15 alkyl sulfates in wastewater before and after STP treatment, of which dodecyl sulfates account for 40% of the total. (OECD 2007). In studies based in the USA and the Netherlands, influent concentrations ranged from 0.078–1.29 mg/L, while effluent concentrations following secondary removal processes (including anaerobic digestion, trickling filter and activated sludge) ranged from 0.24–12 micrograms per litre ($\mu\text{g/L}$) and outfall concentrations ranged from 0.065–0.17 $\mu\text{g/L}$ (Matthijs et al. 1999; Sanderson et al. 2006a).

In Australia, 80% of wastewater is subject to at least secondary treatment (BOM 2020). 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 use activated sludge processes. Internationally, the worst-case concentration of dodecyl sulfates in effluent after trickling filter treatment is 0.03 mg/L. Considering that river flows can consist entirely of STP effluent in some drier parts of Australia, a reasonable worst case environmental concentration of dodecyl sulfates in domestic rivers is predicted to be 0.03 mg/L. The dilution factor for a marine PEC in Australia is 10, so the environmental concentration of dodecyl sulfates in marine waters is predicted to be 0.003 mg/L.

There are no international monitoring data identified for the concentration of dodecyl sulfates in surface waters, but a study analysing total alkyl sulfates (C12–C15) in riverine samples in the US proximal to STPs reported concentrations of 0.01–0.18 $\mu\text{g/L}$ (Sanderson et al. 2006a).

A survey of dodecyl sulfate concentrations in freshwater sediments found concentrations of 0.013–0.021 milligrams per kilogram (mg/kg) dry weight (dw) in the US, collected from a pond and 2 riverine sites downstream from STPs (Sanderson et al. 2006b). The maximum concentration is taken as a conservative estimate of dodecyl sulfate concentrations in Australian freshwater sediments. Dodecyl sulfates were quantified in marine sediments collected from STP outfall sites in Spain with concentrations of 7.5–10.6 mg/kg dw (Fernández-Ramos et al. 2014). The maximum concentration is taken as a conservative estimate of dodecyl sulfate concentrations in Australian marine sediments.

Dodecyl sulfates that are removed by adsorption to sludge in STPs may be released to the environment by application to agricultural soil. Dodecyl sulfate was analysed in sewage sludge before and after anaerobic digestion (14 days). The concentration reduced from 40 mg/kg dw before treatment to 28 mg/kg dw after treatment (Bruno et al. 2002). Anaerobic digestion is a less efficient mitigation pathway than aerobic processes, and the concentration after anaerobic treatment is taken as a conservative estimate of dodecyl sulfate concentrations in sewage sludge.

The calculated concentration of dodecyl sulfates in Australian agricultural soil amended with biosolids is 0.22 mg/kg dw based on the measured anaerobic sludge concentration (28 mg/kg dw), typical biosolids application rates (10 tonnes per hectare [t/ha]) and soil bulk density of 1300 kilograms per cubic metre (kg/m³) (EPHC 2009; Langdon et al. 2010).

Environmental effects

Effects on Aquatic Life

Chemicals in this group have the potential to cause toxic effects in aquatic organisms across multiple trophic levels. Aquatic toxicity of dodecyl sulfates is well studied and acute and chronic endpoints are available for SLS or calcium dodecyl sulfate for many species across multiple trophic levels. These chemicals are suitable for read across to the remaining chemicals in the group because they dissociate to the common dodecyl sulfate anion. Endpoints were not adjusted to account for differences in molecular weight because the proportion of dodecyl sulfate is comparable (93% and 92% by weight in calcium dodecyl sulfate and SLS respectively).

The aquatic toxicity of surfactant chemicals is generally explained by their interaction with cell membranes (Könnecker et al. 2011). Studies have shown that the temperature, water hardness and salinity (for marine or brackish species) have differing effects on toxicity depending on the aquatic species (Freitas et al. 2021; Persoone et al. 1989). These properties are reported when available (water hardness reported as the concentration of calcium carbonate).

Freshwater acute toxicity

The following measured median effective concentration (EC50) and median lethal concentration (LC50) values for freshwater model organisms over 3 trophic levels were taken from the OECD SIDS assessment (OECD 2007), the REACH dossier for SLS (REACHa) and the scientific literature (Fogels and Sprague 1977; Versteeg et al. 1997):

Taxon	Endpoint	Method
Fish	96 h LC50 = 4.6 mg/L	<i>Oncorhynchus mykiss</i> (rainbow trout) Flow-through, nominal concentrations 350–375 mg/L CaCO ₃ , 15°C
Invertebrates	48 h EC50 = 1.4 mg/L	<i>Brachionus calyciflorus</i> (planktonic rotifer) Population increase Static, measured concentrations 152 mg/L CaCO ₃ , 25°C
Algae	72 h EC50 = 53 mg/L	<i>Desmodesmus subspicatus</i> (green algae) Biomass Static, measured concentrations 22.5–24.5°C German standard DIN 38412 part 9

Freshwater chronic toxicity

The following measured no observed effect concentration (NOEC) values for freshwater model organisms across taxa were taken from the REACH dossier for SLS (REACHa) and the scientific literature (Belanger et al. 1995; Dyer et al. 1997; Pickering 1988):

Taxon	Endpoint	Method
Fish	8 d NOEC = 2.2 mg/L	<i>Pimephales promelas</i> (fathead minnow) Growth Semi-static, nominal concentrations 202 mg/L CaCO ₃ , 25°C
Invertebrates	7 d NOEC = 0.88 mg/L	Read across from calcium dodecyl sulfate <i>Ceriodaphnia dubia</i> (water flea) Reproduction Flow-through, measured concentrations 114–205 mg/L CaCO ₃ , 25°C OECD TG 202 (equivalent)
Mollusc	42 d NOEC = 0.42 mg/L	<i>Corbicula fluminea</i> (Asian clam) Growth Flow-through, measured concentrations 13–24°C
Algae	72 h NOEC = 30 mg/L	<i>Desmodesmus subspicatus</i> (green algae) Biomass Static, nominal concentrations German standard DIN 38412 part 9

Marine acute toxicity

The following median lethal concentration (LC50) values for marine species across 2 trophic levels and measured in seawater were taken from the REACH dossier for SLS (REACHa):

Taxon	Endpoint	Method
Fish	96 h LC50 = 2.8 mg/L	<i>Menidia menidia</i> (Atlantic silverside) Static, nominal concentrations ASTM E-35
Invertebrates	96 h LC50 = 3.6 mg/L	<i>Allorchestes compressa</i> (native Australian amphipod) Semi-static, nominal concentrations

Marine chronic toxicity

The following median lethal concentration (LC50) median effective concentration (EC50) and maximum acceptable toxicant concentration (MATC) values for marine species across 3 trophic levels were taken from the REACH dossier for SLS (REACHa), OECD SIDS assessment (OECD 2007) and the scientific literature (Morrison et al. 1989):

Taxon	Endpoint	Method
Fish	7 d LC50 = 1.8 mg/L	<i>Menidia beryllina</i> (inland silverside, larvae) Semi-static, nominal concentrations 5–32‰ salinity, 25°C EPA-821-R-02-014, method 1006.0
Invertebrates	7 d MATC = 2.0 mg/L	<i>Mysidopsis intii</i> (mysid shrimp) Growth Semi-static, nominal concentrations 34‰ salinity, 20°C EPA/600/4-87/028
Algae	48 h EC50 = 0.3 mg/L	<i>Champia parvula</i> (red microalga) Reproduction (number of cystocarps) Static, nominal concentrations 30‰ salinity, 23°C EPA-821-R-02-014, method 1009.0

Effects on sediment dwelling life

The toxicity of SLS toward the marine sediment dwelling amphipod *Tiburonella viscana* was tested in a static test in aqueous solution (34‰ salinity, 25°C) with nominal concentrations. The LC50 after 48 hours of exposure was 3.41 mg/L (Melo and Nipper 2007).

The toxicity of SLS to *Arenicola marina*, a lugworm that inhabits marine tidal flats, was tested in a semi-static test in seawater (15°C) with nominal concentrations. The LC50 after 48 hours of exposure was 15.2 mg/L. When exposed to comparable concentrations (10–20 mg/L) it was observed that the epidermis and gills of the worms were damaged (separations in epithelial layers, holes formed) by exposure to the chemical (Conti 1987).

Endocrine effects/activity

No signs of oestrogenic effects for dodecyl sulfates or their degradants have been identified (Routledge and Sumpter 1996).

Predicted no-effect concentration (PNEC)

A freshwater PNEC for the chemicals in this group of 0.042 mg/L was derived from the measured mollusc chronic toxicity endpoint (42 d NOEC = 0.42 mg/L), using an assessment factor of 10. This assessment factor was selected as reliable chronic ecotoxicity data are available over 3 trophic levels (EPHC 2009).

A marine PNEC for the chemicals in this group of 0.03 mg/L was derived from the measured algal chronic toxicity endpoint (48 h EC50 = 0.3 mg/L), using an assessment factor of 10. This factor was selected as reliable chronic ecotoxicity data are available over 3 trophic levels (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 measured results from standard biodegradability tests and experimental field measurements that show ultimate degradation, the chemicals in this group are categorised as Not persistent.

Bioaccumulation

Not bioaccumulative (Not B). Based on low measured log K_{ow} and bioconcentration factors in fish, the chemicals in this group are categorised as Not bioaccumulative.

Toxicity

Not toxic (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, the following Risk Quotients (RQ = $PEC \div PNEC$) have been calculated for release of the chemicals in this group into rivers and the marine environment:

Compartment	PEC	PNEC	RQ
River	0.03 mg/L	0.042 mg/L	0.7
Marine	0.003 mg/L	0.03 mg/L	0.1

For rivers, an RQ less than 1 indicates that the chemicals in this group 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 marine waters, an RQ less than 1 indicates that the chemicals in this group 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.

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:

- There are no domestic monitoring data for dodecyl sulfate salts in surface waters (freshwater or marine), soil or sediment.
- There are limited international monitoring data for the chemicals in this group preventing a robust weight-of-evidence prediction of environmental concentrations.
- A risk quotient in marine waters and sediment is limited by lack of environmental monitoring data in these compartments.
- A risk quotient in freshwater sediments is limited by lack of available environmental monitoring and ecotoxicity data.
- There is uncertainty about the extent that direct emissions of dodecyl sulfate salts contribute to domestic use volumes.

The risk profile of dodecyl sulfate salts may change should monitoring data become available to indicate that these chemicals are present in Australian environmental compartments at concentrations above the level of concern. The risk profile of dodecyl sulfate salts may change should data become available to suggest that direct environmental emissions, for example from surfactant-enhanced remediation, are a significant emission source.

References

A.I.S.E. and Cefic (2002) [Human and Environmental Risk Assessment on ingredients of European household cleaning products: Alkyl Sulphates Environmental Risk Assessment](#) A.I.S.E (Association for Soaps, Detergents and Maintenance Products) and Cefic (European Chemical Industry Council), accessed June 2022.

Belanger SE, Rupe KL and Bausch RG (1995) 'Responses of invertebrates and fish to alkyl sulfate and alkyl ethoxylate sulfate anionic surfactants during chronic exposure', *Bulletin of Environmental Contamination and Toxicology*, **55**(5), pp 751-758, doi:doi.org/10.1007/BF00203763.

BOM (2020) [National Performance Report 2019-2020: Urban water utilities](#) accessed August 2022.

Bruno F, Curini R, Di Corcia A, Fochi I, Nazzari M and Samperi R (2002) 'Determination of Surfactants and Some of Their Metabolites in Untreated and Anaerobically Digested Sewage Sludge by Subcritical Water Extraction Followed by Liquid Chromatography–Mass Spectrometry', *Environmental Science & Technology*, **36**(19), pp 4156-4161, doi:doi.org/10.1021/es020002e.

Conti E (1987) 'Acute toxicity of 3 detergents and two insecticides in the lugworm, *Arenicola marina* (L.): a histological and a scanning electron microscopic study', *Aquatic Toxicology*, **10**(5), pp 325-334, doi:doi.org/10.1016/0166-445X(87)90006-3.

Cook TM and Goldman CK (1974) 'Degradation of anionic detergents in Chesapeake Bay', *Chesapeake Science*, **15**(1), pp 52-55, doi:doi.org/10.2307/1350960.

Crone S, Vives-Flórez M, Kvich L, Saunders AM, Malone M, Nicolaisen MH, Martínez-García E, Rojas-Acosta C, Catalina Gomez-Puerto M, Calum H, Whiteley M, Kolter R and Bjarnsholt T (2020) 'The environmental occurrence of *Pseudomonas aeruginosa*', *APMIS*, **128**(3), pp 220-231, doi:doi.org/10.1111/apm.13010.

Dyer SD, Lauth JR, Morrall SW, Herzog RR and Cherry DS (1997) 'Development of a chronic toxicity structure–activity relationship for alkyl sulfates', *Environmental Toxicology and Water Quality*, **12**(4), pp 295-303, doi:doi.org/10.1002/(SICI)1098-2256(1997)12:4%3C295::AID-TOX3%3E3.0.CO;2-3.

EC (European Commission) (2004) [B Regulation \(EC\) No 648/2004 of the European Parliament and of the Council of 31 March 2004 on detergents: Annex II](#), EC, accessed June 2022.

EC (European Commission) (2022) [Cosmetic ingredient database](#), EC, accessed June 2022.

EPHC (Environment Protection and Heritage Council) (2009) [Environmental Risk Assessment Guidance Manual for Industrial Chemicals](#), EPHC, accessed July 2022.

Fendinger NJ, Begley WM, McAvoy DC and Eckhoff WS (1992) 'Determination of alkyl sulfate surfactants in natural waters', *Environmental Science & Technology*, **26**(12), pp 2493-2498, doi:doi.org/10.1021/es00036a024.

Fernández-Ramos C, Ballesteros O, Zafra-Gómez A, Camino-Sánchez FJ, Blanc R, Navalón A and Vílchez JL (2014) 'Environmental monitoring of alcohol sulfates and alcohol ethoxysulfates in marine sediments', *Environmental Science and Pollution Research*, **21**(6), pp 4286-4296, doi:doi.org/10.1007/s11356-013-2146-3.

Fogels A and Sprague JB (1977) 'Comparative short-term tolerance of zebrafish, flagfish, and rainbow trout to five poisons including potential reference toxicants', *Water Research*, **11**(9), pp 811-817, doi:doi.org/10.1016/0043-1354(77)90052-5.

Freitas R, Coppola F, Meucci V, Battaglia F, Soares AMVM, Pretti C and Faggio C (2021) 'The influence of salinity on sodium lauryl sulfate toxicity in *Mytilus galloprovincialis*', *Environmental Toxicology and Pharmacology*, **87**, pp 103715, doi:doi.org/10.1016/j.etap.2021.103715.

George AL (2002) 'Seasonal factors affecting surfactant biodegradation in Antarctic coastal waters: comparison of a polluted and pristine site', *Marine Environmental Research*, **53**(4), pp 403-415, doi:doi.org/10.1016/S0141-1136(01)00127-1.

Hodges G, Eadsforth C, Bossuyt B, Bouvy A, Enrici M-H, Geurts M, Kotthoff M, Michie E, Miller D, Müller J, Oetter G, Roberts J, Schowanek D, Sun P and Venzmer J (2019) 'A comparison of log Kow (n-octanol–water partition coefficient) values for non-ionic, anionic, cationic and amphoteric surfactants determined using predictions and experimental methods', *Environmental Sciences Europe*, **31**(1), pp 1, doi:doi.org/10.1186/s12302-018-0176-7.

Könnecker G, Regelman J, Belanger S, Gamon K and Sedlak R (2011) 'Environmental properties and aquatic hazard assessment of anionic surfactants: Physico-chemical, environmental fate and ecotoxicity properties', *Ecotoxicology and Environmental Safety*, **74**(6), pp 1445-1460, doi:doi.org/10.1016/j.ecoenv.2011.04.015.

Kosswig K (2012) Surfactants. In: ed. *Ullmann's Encyclopedia of Industrial Chemistry*, Wiley-VCH, Weinheim, Germany.

Langdon K, Warne M and Kookana R (2010) 'Aquatic hazard assessment for pharmaceuticals, personal care products, and endocrine-disrupting compounds from biosolids-amended land', *Integrated Environmental Assessment and Management*, **6**(4), pp 663-676, doi:doi.org/10.1002/ieam.74.

Lima TMS, Procópio LC, Brandão FD, Carvalho AMX, Tótola MR and Borges AC (2011) 'Biodegradability of bacterial surfactants', *Biodegradation*, **22**(3), pp 585-592, doi:doi.org/10.1007/s10532-010-9431-3.

Liu J-W, Wei K-H, Xu S-W, Cui J, Ma J, Xiao X-L, Xi B-D and He X-S (2021) 'Surfactant-enhanced remediation of oil-contaminated soil and groundwater: A review', *Science of The Total Environment*, **756**, pp 144142, doi:doi.org/10.1016/j.scitotenv.2020.144142.

Marchesi JR, White GF, Russell NJ and House WA (1997) 'Effect of river sediment on the biodegradation kinetics of surfactant and non-surfactant compounds', *FEMS Microbiology Ecology*, **23**(1), pp 55-63, doi:doi.org/10.1111/j.1574-6941.1997.tb00391.x.

Margesin R and Schinner F (1998) 'Biodegradation of the anionic surfactant sodium dodecyl sulfate at low temperatures', *International Biodeterioration & Biodegradation*, **41**(2), pp 139-143, doi:doi.org/10.1016/S0964-8305(97)00084-X.

Marshall SJ, House WA and White GF (2000) 'Role of Natural Organic Matter in Accelerating Bacterial Biodegradation of Sodium Dodecyl Sulfate in Rivers', *Environmental Science & Technology*, **34**(11), pp 2237-2242, doi:doi.org/10.1021/es990828p.

Matthijs E, Holt MS, Kiewiet A and Rijs GBJ (1999) 'Environmental monitoring for linear alkylbenzene sulfonate, alcohol ethoxylate, alcohol ethoxy sulfate, alcohol sulfate, and soap', *Environmental Toxicology and Chemistry*, **18**(11), pp 2634-2644, doi:doi.org/10.1002/etc.5620181133.

McAvoy DC, Dyer SD, Fendinger NJ, Eckhoff WS, Lawrence DL and Begley WM (1998) 'Removal of alcohol ethoxylates, alkyl ethoxylate sulfates, and linear alkylbenzene sulfonates in wastewater treatment', *Environmental Toxicology and Chemistry*, **17**(9), pp 1705-1711, doi:doi.org/10.1002/etc.5620170909.

Melo SLR and Nipper M (2007) 'Sediment toxicity tests using the burrowing amphipod *Tiburonella viscana* (Amphipoda: Platyischnopidae)', *Ecotoxicology and Environmental Safety*, **66**(3), pp 412-420, doi:doi.org/10.1016/j.ecoenv.2005.12.003.

Morrison G, Torello E, Comeleo R, Walsh R, Kuhn A, Burgess R, Tagliabue M and Greene W (1989) 'Intralaboratory precision of saltwater short-term chronic toxicity tests', *Research Journal of the Water Pollution Control Federation*, **61**(11/12), pp 1707-1710

Mukerjee P and Mysels KJ (1971) [Critical Micelle Concentrations of Aqueous Surfactant Systems](#). United States Department of Commerce, National Bureau of Standards accessed June 2022.

NICNAS (2013) [Sodium, ammonium and potassium lauryl sulfate: Human health tier II assessment](#). National Industrial Chemicals Notification and Assessment Scheme accessed June 2022.

NIEHS (National Institute of Environmental Health Sciences) (2022a) [Consumer Product Information Database \(CPID\) Ammonium lauryl sulfate](#). National Institute of Health Sciences (NIH), accessed June 2022.

NIEHS (National Institute of Environmental Health Sciences) (2022b) [Consumer Product Information Database \(CPID\) Sodium lauryl sulfate \(SLS\)](#). National Institute of Health Sciences (NIH), accessed June 2022.

NITE (National Institute of Technology and Evaluation) (2022a) [Japan CHEmicals Collaborative Knowledge Database \(J-CHECK\): Ammonium dodecan-1-yl sulfate](#). NITE, accessed June 2022.

NITE (National Institute of Technology and Evaluation) (2022b) [Japan CHEmicals Collaborative Knowledge Database \(J-CHECK\): Sodium dodecan-1-yl sulfate](#). NITE, accessed June 2022.

Nordic Council of Ministers (2022) [Substances in Preparations in Nordic Countries \(SPIN\)](#). Chemical Group, Nordic Council of Ministers, accessed June 2022.

OECD (Organisation for Economic Co-operation and Development) (1995) *Guidance document for aquatic effects assessment*, OECD, Paris.

OECD (Organisation for Economic Cooperation and Development) (1996) [SIDS Initial Assessment Profile: Sodium dodecyl sulfate \(SDS\)](#), accessed June 2022.

OECD (Organisation for Economic Cooperation and Development) (2007) [SIDS Initial Assessment Report: Alkyl Sulfates, Alkane Sulfonates and alpha-Olefin Sulfonates](#), accessed June 2022.

OECD (The Organisation for Economic Co-operation and Development) (2019) [Guiding Principles and Key Elements for Establishing a Weight of Evidence for Chemical Assessment, Series on Testing and Assessment No. 311, Environment, Health and Safety Division, Environment Directorate](#) OECD, accessed August 2022.

OECD (Organisation for Economic Cooperation and Development) (2022) [OECD Existing Chemicals Database](#), OECD, accessed June 2022.

Painter HA (1992) Anionic Surfactants. In: de Oude NT, ed. *Detergents*, Springer Berlin Heidelberg, Berlin, Heidelberg, pp 1-88.

Paulo AMS, Plugge CM, García-Encina PA and Stams AJM (2013) 'Anaerobic degradation of sodium dodecyl sulfate (SDS) by denitrifying bacteria', *International Biodeterioration & Biodegradation*, **84**, pp 14-20, doi:doi.org/10.1016/j.ibiod.2013.05.027.

Pérez-Carrera E, León VM, Lara-Martín PA and González-Mazo E (2010) 'Influence of the hydrophilic moiety of anionic and nonionic surfactants on their aerobic biodegradation in seawater', *Science of The Total Environment*, **408**(4), pp 922-930, doi:doi.org/10.1016/j.scitotenv.2009.10.003.

Persoone G, Van de Vel A, Van Steertegem M and De Nayer B (1989) 'Predictive value of laboratory tests with aquatic invertebrates: influence of experimental conditions', *Aquatic Toxicology*, **14**(2), pp 149-167, doi:doi.org/10.1016/0166-445X(89)90025-8.

Pickering QH (1988) 'Evaluation and comparison of two short-term fathead minnow tests for estimating chronic toxicity', *Water Research*, **22**(7), pp 883-893, doi:doi.org/10.1016/0043-1354(88)90026-7.

Ramprasad C and Philip L (2016) 'Surfactants and personal care products removal in pilot scale horizontal and vertical flow constructed wetlands while treating greywater', *Chemical Engineering Journal*, **284**, pp 458-468, doi:doi.org/10.1016/j.cej.2015.08.092.

Ramprasad C and Philip L (2018) 'Contributions of various processes to the removal of surfactants and personal care products in constructed wetland', *Chemical Engineering Journal*, **334**, pp 322-333, doi:doi.org/10.1016/j.cej.2017.09.106.

REACHa (Registration, Evaluation, Authorisation and Restriction of Chemicals) (n.d.) [REACH registration dossier for sodium dodecyl sulphate \(CAS RN 151-21-3\)](#), REACH, accessed June 2022.

REACHb (Registration, Evaluation, Authorisation and Restriction of Chemicals) (n.d.) [REACH registration dossier for potassium dodecyl sulphate \(CAS RN 4706-78-9\)](#), REACH, accessed June 2022.

Routledge EJ and Sumpter JP (1996) 'Estrogenic activity of surfactants and some of their degradation products assessed using a recombinant yeast screen', *Environmental Toxicology and Chemistry*, **15**(3), pp 241-248, doi:doi.org/10.1002/etc.5620150303.

Sanderson H, Dyer SD, Price BB, Nielsen AM, van Compernelle R, Selby M, Stanton K, Evans A, Ciarlo M and Sedlak R (2006a) 'Occurrence and weight-of-evidence risk assessment of alkyl sulfates, alkyl ethoxysulfates, and linear alkylbenzene sulfonates (LAS) in river water and sediments', *Science of The Total Environment*, **368**(2), pp 695-712, doi:doi.org/10.1016/j.scitotenv.2006.04.030.

Sanderson H, Price BB, Dyer SD, DeCarvalho AJ, Robaugh D, Waite SW, Morrall SW, Nielsen AM, Cano ML and Evans KA (2006b) 'Occurrence and hazard screening of alkyl sulfates and alkyl ethoxysulfates in river sediments', *Science of The Total Environment*, **367**(1), pp 312-323, doi:doi.org/10.1016/j.scitotenv.2005.11.021.

Singer MM and Tjeerdema RS (1993) 'Fate and Effects of the Surfactant Sodium Dodecyl Sulfate', *Reviews of Environmental Contamination and Toxicology*, **133**, pp 95-149, doi:doi.org/10.1007/978-1-4613-9529-4_3.

Tovell PWA, Howes D and Newsome CS (1975) 'Absorption, metabolism and excretion by goldfish of the anionic detergent sodium lauryl sulphate', *Toxicology*, **4**(1), pp 17-29, doi:doi.org/10.1016/0300-483X(75)90018-9.

UNEP (United Nations Environment Programme) (1987) [The Montreal Protocol on Substances that Deplete the Ozone Layer](#), UNEP, Ozone Secretariat, accessed June 2022.

UNEP (United Nations Environment Programme) (2001) [The Stockholm Convention on Persistent Organic Pollutants](#), UNEP, Secretariat of the Stockholm Convention, accessed June 2022.

UNEP & FAO (United Nations Environment Programme & Food and Agriculture Organization of the United Nations) (1998) [Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade](#), UNEP & FAO accessed June 2022.

US EPA (United States Environmental Protection Agency) (2020) [2020 CDR Industrial Processing and Use](#), US EPA. Downloaded June 2022.

US EPAa (United States Environmental Protection Agency) (n.d.) [Safer Chemical Ingredients List](#), US EPA, accessed June 2022.

US EPAb (United States Environmental Protection Agency) (n.d.) [High Production Volume List](#), US EPA, accessed June 2022.

US EPAc (United States Environmental Protection Agency) (n.d.) [InertFinder: Sodium lauryl sulfate \(Commodity Inert Ingredient\)](#), US EPA, accessed June 2022.

Versteeg DJ, Stanton DT, Pence MA and Cowan C (1997) 'Effects of surfactants on the rotifer, *Brachionus calyciflorus*, in a chronic toxicity test and in the development of qsars', *Environmental Toxicology and Chemistry*, **16**(5), pp 1051-1058, doi:doi.org/10.1002/etc.5620160527.

Vives-Rego J, Vaque MD, Sanchez Leal J and Parra J (1987) 'Surfactants Biodegradation in Sea Water / Biologischer Tensidabbau in Meerwasser', *Tenside Surfactants Detergents*, **24**(1), pp 20-22, doi:doi.org/10.1515/tsd-1987-240110.

Wakabayashi M, Kikuchi M, Kojima H and Yoshida T (1978) 'Bioaccumulation profile of sodium linear alkylbenzene sulfonate and sodium alkyl sulfate in carp', *Chemosphere*, **7**(11), pp 917-924, doi:doi.org/10.1016/0045-6535(78)90124-8.

Wakabayashi M, Kikuchi M, Kojima H and Yoshida T (1980) 'Effect of alkyl chain on the uptake, distribution, and excretion of ³⁵S-labeled alkyl sulfates in carp', *Ecotoxicology and Environmental Safety*, **4**(2), pp 195-206, doi:doi.org/10.1016/0147-6513(80)90020-2.

