Updated September 2017

Environmental Health Standing Committee (enHealth) of the
Australian Health Protection Principal Committee

enHealth Guidance Statements on per- and poly-fluoroalkyl substances

Background and context:

Per- and poly-fluoroalkyl substances, or “PFAS”, are a class of manufactured chemicals that have been used since the 1950s to make products that resist heat, stains, grease and water. Until recently, this group of chemicals was known as “perfluorinated chemicals”, or “PFCs”. The name change has come about to avoid confusion with another group of chemicals that are relevant to climate change, which are also known as “PFCs”.

Products that may contain PFAS include furniture and carpets treated for stain resistance, foams used for firefighting, fast food or packaged food containers, make up and personal care products and cleaning products. Other chemicals used in these applications may be precursors to PFAS, and the PFAS are formed when these chemicals are released into the environment.

PFAS are of concern around the world because they are not readily broken down in the environment and so can persist for a long time. Their widespread use and persistence means that many types of PFAS are ubiquitous global contaminants.

The PFAS of most concern are perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA). Many countries have phased out, or are in the process of phasing out the use of PFOS and PFOA due to concerns about their persistence, bioaccumulation and toxicity. Perfluorohexane sulfonate (PFHxS) is another chemical of the PFAS group and is present in some fire-fighting foams. PFHxS have also been used as raw materials or precursors to produce PFAS-based products.

Because of their widespread use, people in Australia commonly have some PFOS, PFOA and PFHxS in their body. PFOS and PFOA are readily absorbed through the gut, and once these chemicals are in a person’s body it takes about two to nine years, depending on the study, before those levels go down by half, even if no more is taken in.

The Australian Government has been working since 2002 to reduce the importation of some PFAS. In Australia and internationally where the use of PFAS has become restricted, a general trend towards lower PFAS levels in a person’s body has been observed.

Outside of the occupational setting, exposure to PFAS can occur from the air, indoor dust, food, water and various consumer products. For most people food is expected to be the primary source of exposure to these chemicals. Human breast milk may contribute to exposure in infants since some PFAS have been detected in human breast milk.

For some communities near facilities where PFAS have been extensively used, higher levels may be found in the surrounding environment and human exposure may occur through other means, including drinking water supplied from groundwater.

In chronic exposure studies on laboratory animals, research into PFOS and PFOA has shown adverse effects on the liver, gastrointestinal tract and thyroid hormones. However, the applicability of these studies to humans is not well established.

The existing limited studies on PFHxS suggest that this chemical can cause effects in laboratory test animals similar to the effects caused by PFOS. However, based on available studies, PFHxS appears to be less potent in animal studies than PFOS.

In humans, research has not conclusively demonstrated that PFAS are related to specific illnesses, even under conditions of occupational exposure. Recent studies have found possible associations with some health problems, although more research is required before definitive statements can be made on causality or risk.

Because the human body is slow to rid itself of PFAS, continued exposure to these chemicals can result in accumulation in the body. Due to the potential for accumulation, and while uncertainty around their potential to cause human adverse health effects remains, it is prudent to reduce exposure to PFAS as far as is practicable. This means that action needs to be taken to address the exposure source or possible routes of exposure. Determination of exposure is best achieved through a full human health risk assessment that examines all routes of exposure.

It is understandable that communities living in PFAS affected areas may want to know what their level of exposure to PFAS is and what this means for their health and the health of their families. The lack of certainty around the potential for health effects can compound concerns.

A blood test can measure the level of PFAS in a person’s blood and can tell a person about their exposure to PFAS and how their blood PFAS levels compare with the levels seen in the general Australian population. However, these tests are not routine and there is at present insufficient scientific evidence for a medical practitioner to be able to tell a person whether their blood level will make them sick now or later in life, or if any current health problems are related to the PFAS levels found in their blood.

As such, blood tests have no diagnostic or prognostic value and are not recommended for the purpose of determining whether an individual’s medical condition is attributable to exposure to PFAS.

In the absence of any test, including a blood test, being definitive in informing individual risk and clinical management, exposure reduction is the key measure to reduce any possible risks posed by PFAS.

At a population level, blood tests can inform a community that they have been exposed to PFAS at a level above that of the general population. The monitoring of pooled community blood samples over time may help determine the success of exposure reduction measures.

Recognising the difficulty in assessing and communicating the risks posed by PFAS to the community, enHealth has developed these guidance statements on key health issues to support jurisdictional responses to incidents of environmental PFAS contamination.

Environmental Health Standing Committee (enHealth) Guidance Statements:

1. Health impacts from exposure to PFAS

There is currently no consistent evidence that exposure to PFAS causes adverse human health effects.

Because these chemicals persist in humans and the environment, enHealth recommends that human exposure to these chemicals is minimised as a precaution.

2. Major human exposure pathways

For the general community, enHealth considers ingestion of food contaminated with PFAS to be the major human exposure pathway.

In sites contaminated by PFAS, drinking water and specific foods may also be important exposure pathways.

3. Reference values for PFOS, PFOA and PFHxS

On 3 April 2017, the Australian Government Department of Health published health based guidance values for use in site investigations across Australia for PFOS, PFOA and PFHxS.

These values replaced the interim human health reference values adopted by enHealth in June 2016 and are available at health.gov.au/pfas.

4. Breast feeding

The significant health benefits of breast feeding are well established and far outweigh any potential health risks to an infant from any PFAS transferred through breast milk.

enHealth does not recommend that mothers living in or around sites contaminated with PFAS cease breast feeding.

5. Pregnancy

There is currently no consistent evidence that exposure to PFAS causes adverse human health outcomes in pregnant women or their babies.

Nonetheless, enHealth recommends that pregnant women should be considered a potentially sensitive population when investigating PFAS contaminated sites, with a view to minimising their exposure to PFAS.

6. Blood tests

There is currently no accepted clinical treatment to reduce levels of PFAS in the human body.

Given the uncertainty that PFAS are directly linked to adverse health outcomes, blood tests cannot determine if the PFAS levels in a person’s blood will make them sick now or later in life.

Therefore, blood tests are not recommended to determine whether any medical condition is attributable to exposure to PFAS and have no current value in informing clinical management, including diagnosis, treatment or prognosis in terms of increased risk of particular conditions over time.

It is noted that various organisations around the world have collected blood samples from people as part of ongoing investigations into PFAS contamination of soil and water. The purpose of these tests was either as part of a defined research program, or to determine how much of these chemicals may be entering a person’s body. The value of blood testing is limited to assessing exposure, such as monitoring over time, which may help determine the success of exposure reduction measures. However, given the long biological half-life of PFAS, frequent blood monitoring is of no value.

enHealth recommends that:

- blood testing has no current value in informing clinical management; and
- the monitoring of pooled community blood samples over time may help determine the success of exposure reduction measures.

Summary of health effects based on studies in humans[1]

[Extract from a published Monash University report]

It is usual that most health risk assessment projections for humans are based on extrapolations from animal studies. The above sections highlight some of the difficulties in extrapolating such data for PFOA and PFOS, especially in a quantitative sense because of the differences in clearance kinetics.

The primary objective of this section of the report is to review the available evidence suggesting adverse health effects in humans that may be attributable to PFAS exposures. In some instances, the toxicological endpoint of interest is predicted by findings in conventional animal toxicity studies, where the exposures are substantially higher than human exposures arising from background sources (e.g. food) or point sources of pollution. In other cases, the endpoint of interest is not predicted by findings from such studies.

Since 2007-09, the publication of epidemiological studies and other surveys of human exposures have begun to shed more light on the extent to which highdose studies in conventional toxicity studies animals predict potential adverse health effects in humans. Relatively few of these human studies are conventional epidemiological studies and they are mainly of a cross-sectional nature, rather than the more robust case-control studies. However, most of the studies reviewed in this section have addressed the issues by comparing the incidence of disease, or a disease marker, between the highest and lowest quartile or tertiles of the distribution of blood concentrations of PFAS. Essentially, these studies investigate the potential for a dose-related trend in the incidence of an adverse health outcome.

The reported outcomes are therefore ‘associations’ which vary in strength, but there is often doubt as to whether the association can be deemed to be ‘causal’. A common problem with the interpretation of these studies is that, in most cases, the adverse health outcome is assessed against several congeners of the PFAS that have been measured in blood, with multiple studies often demonstrating associations with individual PFAS (e.g. PFOS, PFOA, PFHxS etc), but where the specific PFAS with the strongest associations differing from study to study. In some cases there is also inconsistency across studies with regard to either the direction of the change or the specific disease marker associated with increasing PFAS blood levels.

While these studies in humans have begun to suggest some adverse health effects in those carrying the highest body burdens of PFOS, PFOA of some other PFAS, the evidence generally falls short of proving a causal relationship (Saikat *et al*, 2013). In some cases, the adverse effects are consistent with those seen in

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[1] Extract: Chapter 5 of: Professor Brian Priestly, *Literature Review and Report on the potential health effects of perfluoroalkyl compounds, mainly perfluorooctane sulfonate (PFOS) (an update of a review initially prepared in 2010 and 2015)* (School of Public Health and Preventive Medicine, Monash University, 2016). Full report available: https://www2.health.vic.gov.au/about/publications/researchandreports/literature-review-report-on-potential-health-effects-of-perfluoroalkyl-compounds.

animals (e.g. the lipid and foetal developmental effects), while other effects on serum uric acid, and possibly the neurobehavioural developmental effects (possibly mediated via disturbance of thyroid hormone functions?) have not been observed in animal studies.

Most of these human studies have assessed the health impacts of PFAS in populations with relatively low (background) blood levels. There are also a few studies where the groups studied have been exposed to point sources of pollution. For example, the C8 Health study generated a number of papers on residents who lived around the DuPont Washington Works PFAS production facility near Parkersbug, West Virginia, that contaminated water supplies with PFOA in the mid-Ohio Valley and neighbouring regions The project enrolled around 69,030 people, and measured blood levels of PFOA were generally up to 10-100x higher than in the general U.S. population, while six other PFAS (including PFOS) were generally more towards general population levels (Frisbee *et al*, 2009).

In contrast, conventional epidemiological studies have often failed to demonstrate comparable health deficits in workers exposed occupationally to PFAS, despite these workers having body burdens 1-2 orders of magnitude higher that the general population (Olsen *et al*, 2003). In a review of the state of epidemiological knowledge at 2010, Steenland *et al* (2010a) acknowledged that most of the associations reported at that time were modest, inconsistent across studies and PFAS analysed, and required further confirmatory research using larger cohorts.

The full report is available at the following website:

Extract of: Professor Brian Priestly, *Literature Review and Report on the potential health effects of perfluoroalkyl compounds, mainly perfluorooctane sulfonate (PFOS) (an update of a review initially prepared in 2010 and 2015)* (School of Public Health and Preventive Medicine, Monash University, 2016). Full report available: https://www2.health.vic.gov.au/about/publications/researchandreports/literature-review-report-on-potential-health-effects-of-perfluoroalkyl-compounds

Summary: possible health effects of per- and poly-fluoroalkyl substances (PFAS)

- The scientific community is uncertain about the potential effects on people living in contaminated areas. More research is being done now and our understanding of any possible health effects of PFAS exposure will grow.
- Most research into the health effects of PFAS is relatively recent. Most studies have looked at effects on animals (who can respond differently to humans) or in people who have had extremely high exposure through working for manufacturers of PFAS-containing products.
- As PFAS are known to be persistent and bioaccmulative in the environment, governments globally are recommending a precautionary approach to their management—advising to reduce use and exposure as far as practicable.

Human studies

- There is a lack of scientific data to date, particularly with people. Research has found an ‘association’ between PFOS exposure with increased cholesterol and triglycerides, and changes in thyroid hormones. An association between PFOA exposure in pregnant women and reduced birth weight has also been found. However, these studies have not determined whether it is PFAS or another factor that causes the changes.
    - To date, there is no proven causal relationship between PFAS exposure and adverse human health effects.
- Blood levels of PFAS in PFAS factory workers have been found to be 100 – 1 000 times higher than the general population. There is still no conclusive evidence of exposure to PFAS causing illness in humans.
- After exposure, it takes about 3.8 years for perfluorooctanoic acid (PFOA) and 5.4 years for perfluorooctane sulfonate (PFOS) for half of the chemical to be excreted from the body.

Animal studies

- Studies in animals and cultured cells show various toxicities for PFAS. These can be alarming for the public to read, and determining the relevance of these findings to humans is complex.
- PFOS and PFOA are readily absorbed after ingestion, and are mainly stored in the liver, lungs, kidneys and blood. They also cross the protective brain and placenta membrane barriers.
- PFOS or PFOA are not converted into anything else in the body (not metabolised) and are eliminated mainly in the urine. Elimination takes days for animals compared to years for humans.
- PFOS and PFOA do not damage DNA (are non-genotoxic) in animal and cultured cell studies.
- Studies observing liver tumours in animals suggest that both PFOS and PFOA may be carcinogenic (have potential to cause cancer) with prolonged exposure to high levels.
- For hormones, animal studies showed PFOS can increase oestradiol, change thyroid hormone levels, and increase noradrenaline in the brain. PFOA decreased testosterone levels.
- PFOS interferes with the metabolism of fatty acids, lipids and lipoproteins, which can disrupt normal cell transport and communication systems in animal and cultured cell studies.
- PFOS and PFOA adversely impacted immune system responsiveness, but varying results were seen at different doses in some animal studies and more immunotoxicity research is needed.
- PFOS and PFOA caused reproductive and developmental toxicity in animal studies. However, the underlying mechanism for this toxicity remains unclear.

One page only – February 2017

Document 10

Environment Tier II Assessment for Direct Precursors to Perfluoroheptanesulfonate (PFHpS), Perfluorohexanesulfonate (PFHxS) and Perfluoropentanesulfonate (PFPeS)

Preface

This assessment was carried out under the National Industrial Chemicals Notification and Assessment Scheme (NICNAS). This scheme has been established by the *Industrial Chemicals (Notification and Assessment) Act 1989* (the Act), to aid in the protection of the Australian people and the environment by assessing the risks of industrial chemicals, providing information and making recommendations to promote their safe use.

As part of reforms regarding Existing Chemicals, NICNAS has implemented a new framework to address the human health and environmental impacts of previously unassessed industrial chemicals listed on the Australian Inventory of Chemical Substances (AICS).

The Inventory Multi-tiered Assessment and Prioritisation (IMAP) framework was developed with significant input from stakeholders. The framework provides a more rapid, flexible and transparent approach for the assessment of existing chemicals.

Stage One of this program, which is being undertaken over four years from 1 July 2012, is examining 3000 chemicals meeting characteristics identified by stakeholders as needing priority assessment. This includes chemicals for which NICNAS already holds exposure information, chemicals identified as a concern or for which regulatory action has been taken overseas, and chemicals detected in international studies analysing chemicals present in babies' umbilical cord blood.

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

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

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

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

Disclaimer

NICNAS has made every effort to assure the quality of information available in this report. However, before relying on it for a specific purpose, users should obtain advice relevant to their particular circumstances. This report has been prepared by NICNAS using a range of sources, including information from databases maintained by third parties, which include data supplied by industry. NICNAS has not verified and cannot guarantee the correctness of all information obtained from those databases. Reproduction or further distribution of this information may be subject to copyright protection. Use of this information without obtaining the permission from the owner(s) of the respective information might violate the rights of the owner. NICNAS does not take any responsibility whatsoever for any copyright or other infringements that may be caused by using this information.

Acronyms & Abbreviations

Grouping Rationale

This Tier II assessment considers the environmental risks associated with the industrial uses of nine related perfluorinated chemicals. The chemicals in this group include salts (and an acid fluoride derivative) of long-chain perfluoroalkyl sulfonic acids containing seven or six perfluorinated carbons, and salts of an intermediate chain length acid with five perfluorinated carbons.

All of the chemicals in this group are expected to hydrolyse and/or dissociate into the perfluoroheptanesulfonate anion (PFHpS), the perfluorohexanesulfonate anion (PFHxS) or the perfluoropentanesulfonate anion (PFPeS), respectively, in the aquatic environment.

The perfluorinated anions released by the chemicals in this group have chain lengths which complete the series between the homologous C_4 perfluorobutanesulfonate anion (PFBS) and the C_8 perfluorooctanesulfonate anion (PFOS). Data currently available for simple salts of PFBS indicate that although this short-chain anion is exceptionally persistent in the environment, it is not bioaccumulative or toxic (NICNAS, 2015a). However, the long-chain PFOS anion is persistent, bioaccumulative, and toxic, and substances which release this anion are considered to pose a significant hazard both to human health and the environment (NICNAS, 2015d; 2015e).

Perfluorooctanesulfonic acid, its salts and perfluorooctane sulfonyl fluoride have recently been identified as Persistent Organic Pollutants (POPs) under Annex B of the *Stockholm Convention on Persistent Organic Pollutants* (the Stockholm Convention). These substances are also listed on Annex III of the *Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade* (the Rotterdam Convention). These listings on two global conventions on chemicals have led to significant and evolving international restrictions on industrial uses of perfluoroalkyl sulfonates containing eight perfluorinated carbons. Further information on PFOS can be found in the IMAP Environment Tier II Assessment of the Direct Precursors to Perfluorooctanesulfonate (PFOS) group (see NICNAS, 2015d).

Under the NICNAS action plan for assessing and managing chemicals that could degrade to perfluorinated carboxylic acids, perfluoroalkyl sulfonates and similar chemicals, hazard information for PFOS is used to estimate the hazard of perfluoroalkyl sulfonate degradation products (with four or more perfluorinated carbons), unless sufficient toxicological data are available to demonstrate a lower toxicity profile. More information on the plan can be found in Appendix G of the NICNAS Handbook for Notifiers on the NICNAS website (NICNAS, 2015f).

This assessment will evaluate:

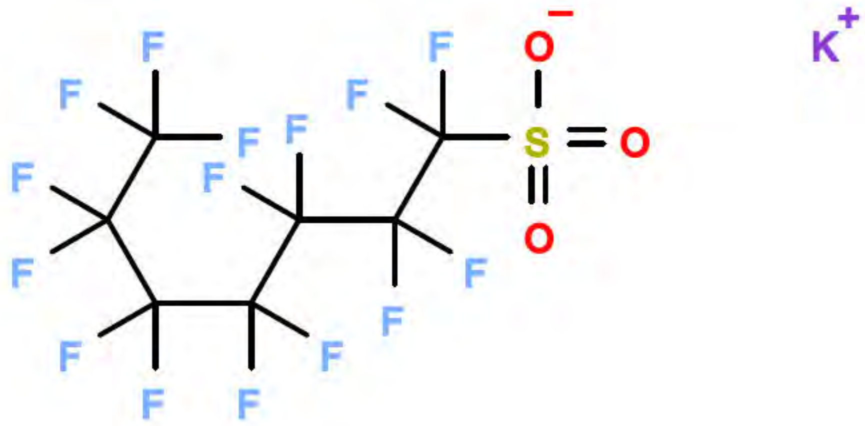
a) the properties of the chemicals in this group and compare them with both PFOS and short-chain homologues; and

b) whether there are sufficient data to use in place of the default assumptions of the action plan.

The assessment of these chemicals as a group also provides additional relevant information for the risk assessment of more complex derivatives of PFHpS, PFHxS and PFPeS which may degrade to these perfluoroalkyl sulfonates in the environment. These more complex derivatives have been assessed separately as the Indirect Precursors to Perfluoroalkyl Sulfonates group (NICNAS, 2015g).

Chemical Identity

In this assessment, "PFHpS" is used to denote the conjugate base anion of perfluoroheptanesulfonic acid (i.e. the perfluoroheptanesulfonate anion), "PFHxS" is used to denote the conjugate base anion of perfluorohexanesulfonic acid (i.e. the perfluorohexanesulfonate anion), and "PFPeS" is used to denote the conjugate base anion of perfluoropentanesulfonic acid (i.e. the perfluoropentanesulfonate anion) (Buck, et al., 2011).

CAS RN	60270-55-5
Chemical Name	1-Heptanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,7-pentadecafluoro-, potassium salt
Synonyms	potassium PFHpS potassium perfluoroheptanesulfonate potassium pentadecafluoroheptanesulfonate
Structural Formula	
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Molecular Weight (g/mol)	488.21

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CAS RN	68259-07-4
Chemical Name	1-Heptanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,7-pentadecafluoro-, ammonium salt
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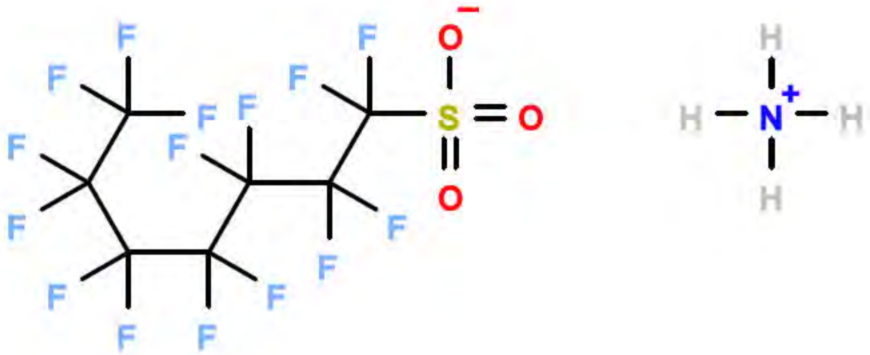
Structural Formula	
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CAS RN	70225-15-9

Chemical Name	1-Heptanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,7-pentadecafluoro-, compound with 2,2′-iminobis[ethanol] (1:1)
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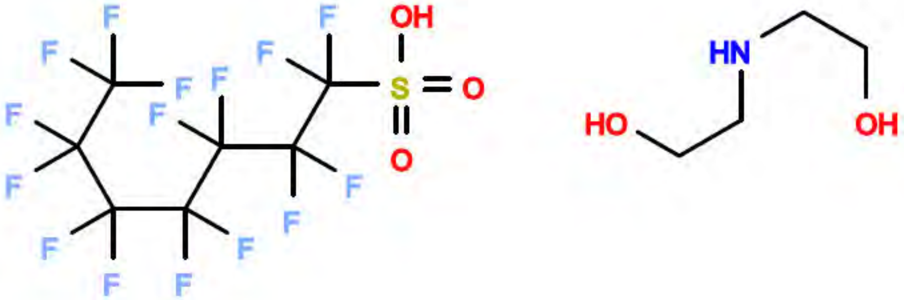
Structural Formula	
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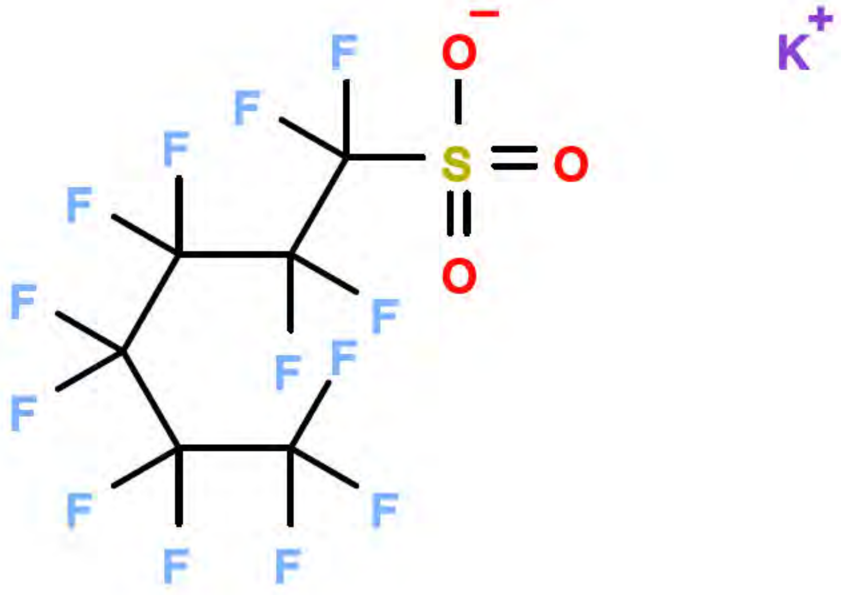
CAS RN	3871-99-6
Chemical Name	1-Hexanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,6-tridecafluoro-, potassium salt
Synonyms	potassium PFHxS potassium perfluorohexanesulfonate

Structural Formula	
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CAS RN	68259-08-5
Chemical Name	1-Hexanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,6-tridecafluoro-, ammonium salt
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	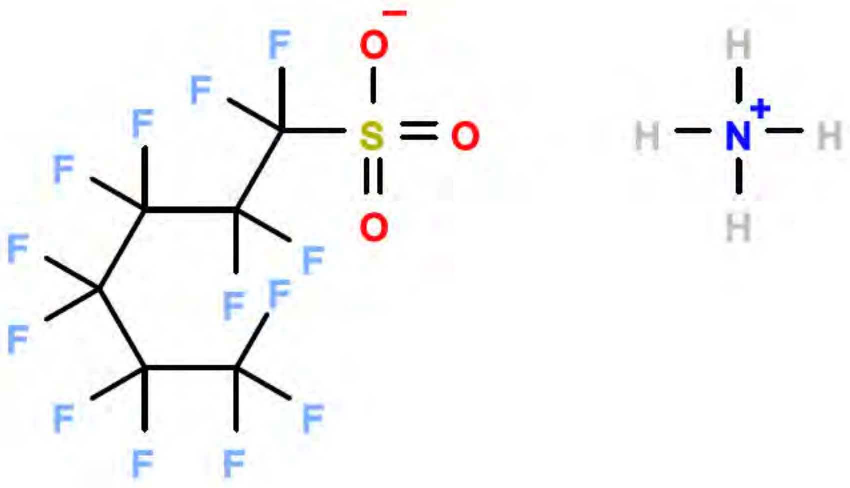
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	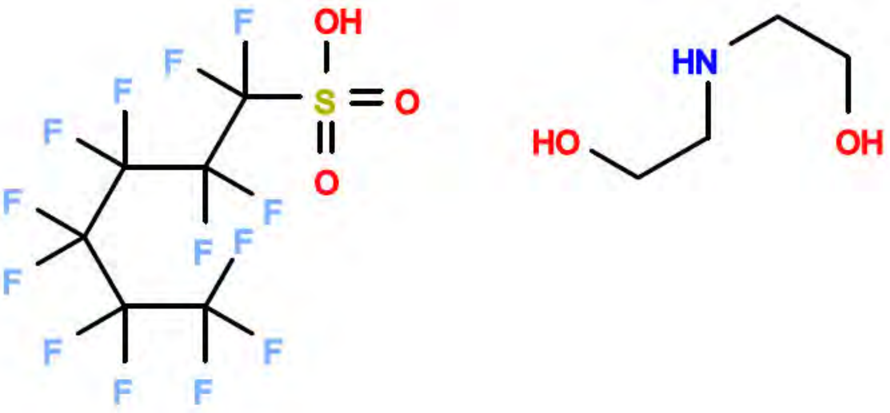
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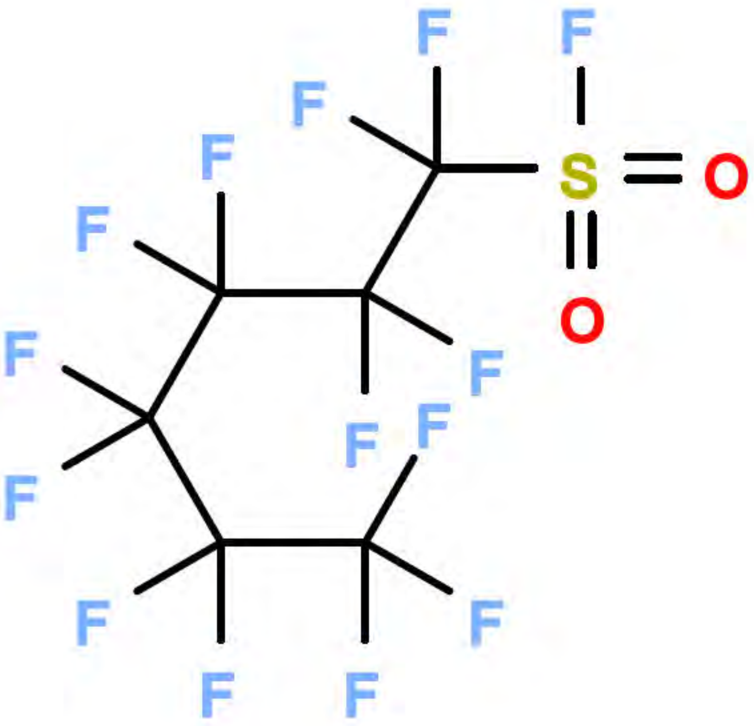
CAS RN	423-50-7
Chemical Name	1-Hexanesulfonyl fluoride, 1,1,2,2,3,3,4,4,5,5,6,6,6-tridecafluoro-
Synonyms	PFHxSF PHxSF perfluorohexanesulfonyl fluoride
Structural Formula	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Molecular Weight (g/mol)	402.11
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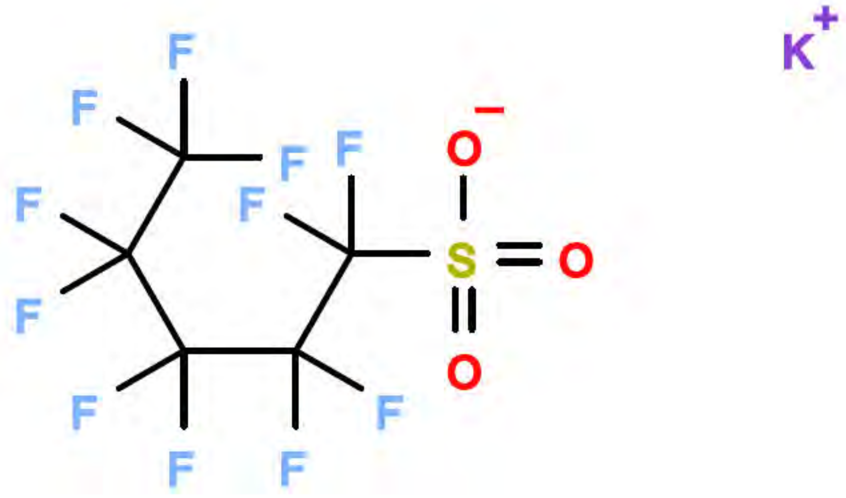
CAS RN	3872-25-1
Chemical Name	1-Pentanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,5-undecafluoro-, potassium salt
Synonyms	potassium PFPeS potassium perfluoropentanesulfonate

Structural Formula	
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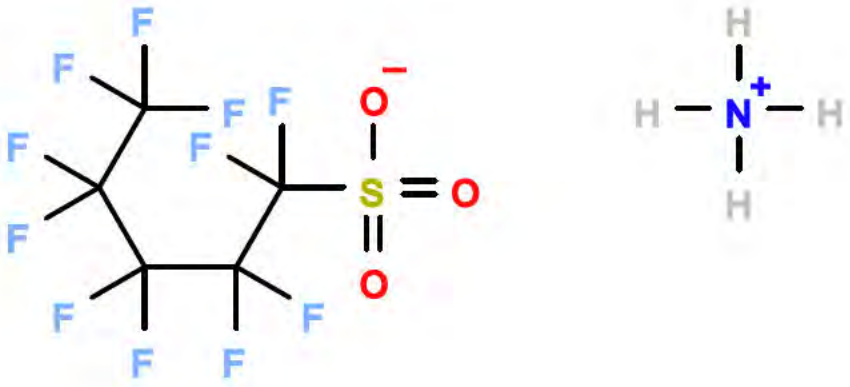
CAS RN	68259-09-6
Chemical Name	1-Pentanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,5-undecafluoro-, ammonium salt
Synonyms	ammonium PFPeS ammonium perfluoropentanesulfonate
Structural Formula	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Physical and Chemical Properties

No measured physical and chemical property data were identified for the chemicals in this group. The measured data available for the properties of the two salts, potassium perfluorobutanesulfonate (potassium PFBS) and potassium perfluorooctanesulfonate (potassium PFOS), are presented below to define the range of values expected for simple salts of perfluoroalkyl sulfonic acids in this group (NICNAS, 2015a; 2015d). Based on these data, the salts in this group are all expected to be solids with moderate solubility in pure water and low volatility:

Chemical	potassium PFBS	potassium PFOS
Physical Form	Solid	Solid
Melting Point	270°C (exp.)	≥ 400°C (exp.)
Vapour Pressure	$< 1.22 \times 10^{-5}$ Pa (exp.)	3.31×10^{-4} Pa (exp.)

Water Solubility	52.6-56.6 mg/L (exp.)	570 mg/L (exp.)

The parent acids for the salts in this group are expected to be very strong acids in water, and to be surface active (NICNAS, 2015a; 2015d). The octanol-water partition coefficient (K_{OW}) parameter is not considered to provide a reliable indicator of the partitioning behaviour of surface-active perfluorinated anions in the environment, and does not form part of the standard set of chemical property data for these chemicals (OECD, 2002).

The available data for homologous sulfonyl fluorides suggest that PFHxSF will be only slightly soluble in water. However, the chemical is expected to highly volatile. The measured values for the vapour pressure of the C_4 and C_8 perfluoroalkyl sulfonyl fluorides are reported to be 16 665 and 213 Pa, respectively (NICNAS, 2015a; 2015d). The hydrolysis of perfluoroalkyl sulfonyl fluorides is relatively slow in water under acid and neutral conditions, and the rate of hydrolysis decreases with increasing carbon chain length (Gramstad and Haszeldine, 1957). The half-life for hydrolysis of the short-chain homologue (perfluorobutanesulfonyl fluoride; CAS RN 375-72-4) has been reported as 73 hours at pH 7 and 23°C (NICNAS, 2015a).

Import, Manufacture and Use

Australia

No specific Australian use, import, or manufacturing information has been identified. However, general information on the use of perfluoroalkyl sulfonates has been reported. The most recent data collected by NICNAS indicate that perfluoroalkyl sulfonates are predominantly used in Australia in mist suppressants for the metal plating industry and in fire fighting foams. Approximately 60 tonnes of fire fighting foams containing perfluoroalkyl sulfonates at concentrations up to 5% were held in Australia in 2007. Other uses included carpet treatments, curatives, industrial coatings and printing inks (NICNAS, 2013a).

In 2004, it was reported that 1.6 tonnes of perfluoroalkyl sulfonates and related chemicals were imported into Australia. By 2007, the imported quantity of these chemicals had increased to 13.6 tonnes. It was reported that the majority of these imports were of chemicals based on the C_4 homologue, perfluorobutanesulfonic acid. The chemicals in this group are not manufactured in Australia (NICNAS, 2013a).

It is noted that the chemicals in this group may be present in the environment due to historic use, release from pre-treated articles, or the use of other chemicals not in this group (which may degrade to these chemicals or contain these chemicals as contaminants). However, release from these uses is beyond the scope of this assessment.

International

Salts of PFHpS, PFHxS and PFPeS have previously been reported to have use as components of etchants for electroplating, in antireflective coatings for photolithography, in photoresists, in carpet treatments and in fire-fighting foams (Beesoon, et al., 2012; Liu and Chang, 2014; OECD, 2011; Olsen, et al., 2005; UNEP, 2007). However, concerns regarding the persistence and bioaccumulation hazards of long-chain perfluoroalkyl sulfonates resulted in the largest manufacturer of these chemicals ceasing their production in 2002 (Buck, et al., 2011). This is expected to have significantly reduced the global supply of most chemicals in this group.

However, subsequent to the cessation in production by the major manufacturer, the diethanolammonium salt of PFHxS was reported to be used as a component of etchants for electroplating (UNEP, 2007). Limited data are available to evaluate the degree to which the remaining salts in this group are used for the above listed purposes. Nevertheless, it is noted that use of the three potassium salts in this group was reported in 2012 in Denmark (Nordic Council of Ministers, 2015).

The sulfonyl fluoride is expected to be used as a chemical intermediate in the production of other fluorochemicals. Manufacture of the chemical was reported in 2008 (OECD, 2011).

Environmental Regulatory Status

Australia

In 2008, a factsheet published by NICNAS recommended that PFOS-based and related PFAS-based chemicals be restricted to essential uses only, and that importers ensure that alternative chemicals are less toxic and not persistent in the environment (NICNAS, 2013a).

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).

OECD

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

The OECD has been leading an international collaboration on the scientific assessment of, and surveys of, perfluorinated chemicals. Since July 2000, Australia has been actively involved in this work through NICNAS.

Canada

Substances having perfluoroheptyl derivatives with the formula C_7F_{15} as a structural element, except those derivatives with the formula C_7F_{15}-X, where X = F, Cl, Br are listed under Schedule 1 (the Toxic Substances List) of the *Canadian Environmental Protection Act 1999* (Government of Canada, 1999). A proposal to prohibit the import, manufacture and use of these chemicals has been released, and is expected to be finalised by January 2016 (Environment Canada, 2012).

All chemicals in this group, apart from PFHxSF, are listed on the Canadian Domestic Substances List (DSL). During the Categorization of the DSL, ammonium PFHpS and diethanolammonium PFHpS were identified as Persistent (P), Bioaccumulative (B) and Inherently Toxic to the Environment (iT_E). All remaining salts in the group were also found to be P. Ammonium PFHxS was found to be B and Not iT_E, while potassium PFHpS and diethanolammonium PFHxS were found to be Not B but iT_E. The three remaining chemicals were found to be Not B and Not iT_E (Environment Canada, 2013a).

Four chemicals in this group (potassium PFHpS, ammonium PFHpS, diethanolammonium PFHpS and diethanolammonium PFHxS) were prioritised for further assessment. The subsequent screening assessment found that these chemicals were not entering the environment in a manner which posed a danger to the environment (Environment Canada, 2015).

European Union

Substances having linear or branched perfluoroheptyl derivatives with the formula C_7F_{15} as a structural element, including its salts except those derivatives with the formula C_7F_{15}-X, where X = F, Cl, Br are subjected to a current restriction proposal to ban the manufacture, use and placing on the market as substances on their own, as constituents of other substances, in a mixture or in articles (ECHA, 2015c).

All chemicals in this group have been pre-registered, but have not yet undergone the full registration process, under the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) legislation (ECHA, 2015a; 2015b).

United States of America

New uses of the chemicals in this group in the United States of America are prohibited without prior approval from the United States Environmental Protection Agency (US EPA) (United States Government, 2002; 2007).

The US EPA published an action plan on long-chain perfluorinated chemicals, covering perfluoroheptanesulfonic acid, perfluorohexanesulfonic acid, and their salts and precursors, in 2009. All chemicals were identified as persistent, bioaccumulative and toxic (US EPA, 2009).

Environmental Exposure

Based on the available domestic and international information, previous uses of the chemicals in this group are considered to have been potentially diverse, including use in fire-fighting foams and carpet treatments. However, use of the chemicals in this group is expected to have been largely phased out due to international concerns regarding the persistence and bioaccumulation hazards of long-chain perfluoroalkyl sulfonates (Buck, et al., 2011). Any current industrial uses are expected to be specialist and low volume in nature. Therefore, direct release of the chemicals to the environment as a result of current industrial uses is considered unlikely, as these chemicals are not expected to have significant use in Australia.

The chemicals in this group are considered more likely to be released to the environment from the use and disposal of other perfluorinated chemicals, which may contain the chemicals in this group as impurities or degrade to them in the environment. However, this exposure route is beyond the scope of this assessment. Indirect releases of the chemicals in this group as a result of environmental degradation of other industrial perfluorinated chemicals listed on AICS have been considered in the Indirect Precursors to Perfluoroalkyl Sulfonates group (NICNAS, 2015g).

The potassium and ammonium cations present as counterions in salts of this group are ubiquitous, naturally occurring inorganic species that are essential for many biological functions. The diethanolammonium cations present as counterions in salts of this group are expected to be readily biodegradable with minimal excess toxicity. The environmental fate and effects of these cations are not further considered in this assessment.

Environmental Fate

Dissolution, Speciation and Partitioning

The salts in this group will dissolve to release perfluoroalkyl sulfonate anions, which are expected to remain in the water compartment.

Perfluoroalkyl sulfonic acids are very strong acids in water and under environmental conditions these acids will exist predominantly as the conjugate base anion (NICNAS, 2015d). The salts of these strong acids will dissociate into their constituent ions in water. The partitioning behaviour of the acids and their salts in the aquatic compartment will be influenced by the surface activity of the perfluorinated anions. Previous studies have indicated that perfluoroalkyl sulfonate anions with less than nine perfluorinated carbons should be expected to remain in water if released to this compartment, unless adsorbed to particulate matter or assimilated by organisms (NICNAS, 2015a; 2015d). However, it is noted that traditional partitioning assumptions may not be appropriate for these chemicals (OECD, 2002).

The sulfonyl fluoride is expected to be less soluble in water than the salts, and to be highly volatile. Based on these properties, this chemical should be expected to experience enhanced partitioning to the atmosphere, with less partitioning to water.

Degradation

The chemicals in this group are expected to be highly resistant to degradation.

Multiple studies conducted on a range of perfluorinated substances, including the C_4 and C_8 homologues of the chemicals in this group, have found no evidence of potential for biodegradation, hydrolysis or aqueous photolysis under environmental conditions (NICNAS, 2015a; 2015b; 2015d).

In the environment, PFHxSF is expected to hydrolyse to release PFHxS. The rate of hydrolysis is unknown. Based on data available for the C_8 homologue (NICNAS, 2015d), PFHxSF is also expected to be resistant to atmospheric degradation.

Bioaccumulation

The perfluoroheptanesulfonate and perfluorohexanesulfonate anions are bioaccumulative. The bioaccumulation potential of the perfluoropentanesulfonate anion is uncertain.

Perfluorinated chemicals have been observed to bioaccumulate by binding to proteins in plasma and liver, rather than the more conventional partitioning to fatty tissue (Ng and Hungerbühler, 2014). The C_8 homologue of the chemicals in this group has been found to be highly bioaccumulative when taking into account accumulation in protein-rich tissues, but also based on high biomagnification factors measured in wildlife (NICNAS, 2015d). However, information currently available for the C_4 homologue, PFBS, indicates that this short-chain perfluorinated anion does not pose a bioaccumulation hazard (NICNAS, 2015a).

Studies considering fish muscle have found PFHxS to have low to moderate bioaccumulation potential in fish. For example, concentrations published following a field study conducted in China allow calculation of whole body bioaccumulation factors (BAF) between 157 and 1784 L/kg for various species of fish (Fang, et al., 2014). However, when considering liver concentrations, PFHxS has been found to have high biomagnification potential. Biomagnification factors (BMF) between 6 and 8.5 have been obtained for liver concentrations of PFHxS from various prey-predator relationships in the Barents Sea (Haukås, et al., 2007). This is consistent with studies that find PFHxS to have a longer bio-elimination half life than PFOS in some terrestrial mammals (Lau, et al., 2007; OECD, 2013b). Therefore, this chemical is considered to be bioaccumulative.

No bioaccumulation data were identified for PFHpS or PFPeS. It has previously been reported that the bioaccumulation potential of perfluoroalkyl sulfonates increases with chain length (Martin, et al., 2003a; Martin, et al., 2003b; Ng and Hungerbühler, 2014). Therefore, as PFHpS has a chain length between the two bioaccumulative immediate homologues, PFHxS and PFOS, this long-chain perfluorinated anion is also expected to be bioaccumulative.

The C_5 homologue, PFPeS, is intermediate in chain length between PFBS, which is not currently considered to pose a bioaccumulation hazard, and PFHxS, which is bioaccumulative. It is currently not possible to determine which of these two immediate homologues best represents the likely bioaccumulation potential of PFPeS. Nevertheless, it is noted that one study has found estimated concentrations of PFPeS in the liver of young seals to be up to ten times higher than those of PFBS in the late 1990s. While work conducted in the early 2000s failed to detect PFBS, PFPeS was detected in all samples. In more recent times, as production of PFBS has increased, estimated concentrations of PFPeS have continued to exceed PFBS by a factor of three (Ahrens, et al., 2009). Based on these data, it is concluded that PFPeS may be bioaccumulative, although the magnitude of the bioaccumulation hazard is currently uncertain.

Transport

Perfluorohexanesulfonate is a globally distributed environmental contaminant. The remaining chemicals in this group have potential to become globally distributed pollutants.

Numerous studies have identified various perfluoroalkyl sulfonates in locations worldwide. Perfluorobutanesulfonate has been detected in the Greenland Sea, while PFOS has been found in Alaska, the Northern Baltic Sea, the Arctic and Antarctica (NICNAS, 2015a; 2015d). The global distribution of perfluoroalkyl sulfonates as environmental contaminants has been difficult to rationalise in terms of conventional long range transport pathways. It has been hypothesised that such distribution may occur through transport in surface water or oceanic currents, transport of volatile precursors, adsorption to particles and/or through living organisms (UNEP, 2006).

Monitoring data available for PFHxS indicate that it is also a globally distributed pollutant, with this perfluorinated anion being detected in the liver of Arctic polar bears, in the Atlantic Ocean, and in Antarctic fur seals (Benskin, et al., 2012; Greaves, et al., 2012; Schiavone, et al., 2009; Smithwick, et al., 2005; Zhao, et al., 2012). Limited data are available for PFHpS, but it has been identified in Arctic foxes (Aas, et al., 2014).

No monitoring data were identified for PFPeS to provide evidence for long-range transport. Nevertheless, perfluoroalkyl sulfonates with shorter chains are expected to have increased potential to undergo long-range transport through surface water and ocean currents (NICNAS, 2015a). Based on monitoring data available for the similarly persistent and highly mobile C_4 homologue, PFPeS is also considered to have potential to become a globally distributed pollutant.

Predicted Environmental Concentration (PEC)

The chemicals in this group are not expected to have significant current industrial use in Australia and PEC values have therefore not been calculated.

Nevertheless, the chemicals in this group may be present in the environment due to past industrial use of other perfluorochemicals contaminated with these substances, use in articles, or from the use of perfluorinated chemicals which degrade to these substances in the environment. In Australia, PFHxS has been detected in 100% of water samples taken from the Parramatta River (main tributary of Sydney Harbour), with a mean concentration of 3.7 nanograms per litre (ng/L) (Thompson, et al., 2011b). The chemical has been detected in Australian drinking water at concentrations up to 13 ng/L (Thompson, et al., 2011a). Sampling of the Brisbane River catchment following a major flooding event in 2011 also found PFHxS present in water at Somerset Dam, Jindalee, Oxley Creek, West End, Bulimba and Moreton Bay. The chemical was detected in all samples obtained at these sites in concentrations ranging between 0.09 and 17 ng/L (Gallen, et al., 2014).

No Australian monitoring data were identified for PFPeS or PFHpS. In addition, limited monitoring data are available internationally for these chemicals. However, PFHpS has recently been identified in effluent from sewage treatment plants in Spain at a mean concentration of 2.91 ng/L. The chemical was also found in sludge at a mean concentration of 1.98 nanograms per gram (ng/g) (Campo, et al., 2014).

Environmental Effects

The potential long-term toxicity of these chemicals is uncertain.

No measured aquatic toxicity data were available for the chemicals in this group. In addition, limited mammalian toxicity data are available. One study conducted in rats has found PFHxS to have low reproductive and developmental toxicity (Butenhoff, et al., 2009; NICNAS, 2015c). However, the relevance of this single study to toxicity in aquatic organisms is unclear.

The findings available for other perfluorinated acids indicate that the primary toxicity concern for these substances is chronic, intergenerational toxicity. Fish toxicity data available for the C_8 homologue, PFOS, indicate potential for increased mortality in offspring when the parent generation are exposed to concentrations as low as 0.01 milligrams per litre (mg/L) (NICNAS, 2015d). However, other studies indicate that the toxicity of perfluoroalkyl sulfonates decreases with chain length (Hagenaars, et al., 2011; Ulhaq, et al., 2013). Consistent with this trend, data currently available for the C_4 homologue, PFBS, do not indicate a potential for high chronic toxicity (NICNAS, 2015a).

Although the toxicity of the perfluoroalkyl sulfonate anions in this group is expected to decrease with perfluorinated chain length, there are insufficient data to reliably interpolate the chronic ecotoxicity of the chemicals in this group from the effects of short and long-chain homologues. Therefore, the chronic ecotoxicity of the chemicals in this group is currently uncertain.

Predicted No-Effect Concentration (PNEC)

Use of the chemicals in this group will result in the environmental release of the PFPeS, PFHxS and PFHpS anions, which are persistent and either bioaccumulative, or potentially bioaccumulative. These two hazard characteristics combined have the potential to result in a range of long term effects on organisms exposed to these chemicals which cannot be readily identified through standard ecotoxicity tests.

For such chemicals, it is not currently possible to estimate a safe exposure concentration using standard extrapolation methods based on laboratory screening levels tests. Predicted no-effects concentrations have therefore not been derived for the chemicals in this group.

Categorisation of Environmental Hazard

The categorisation of the environmental hazards of 1-heptanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,7-pentadecafluoro-, potassium salt (potassium PFHpS); 1-heptanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,7-pentadecafluoro-, ammonium salt (ammonium PFHpS); 1-heptanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,7-pentadecafluoro-, compounds with 2,2′-iminobis[ethanol] (1:1) (diethanolammonium PFHpS); 1-hexanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,6-tridecafluoro-, potassium salt (potassium PFHxS); 1-hexanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,6-tridecafluoro-, ammonium salt (ammonium PFHxS); 1-hexanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,6-tridecafluoro-, compound with 2,2′-iminobis[ethanol] (1:1) (diethanolammonium PFHxS); 1-hexanesulfonyl fluoride, 1,1,2,2,3,3,4,4,5,5,6,6,6-tridecafluoro- (PFHxSF); 1-pentanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,5-undecafluoro-, potassium salt (potassium PFPeS); and 1-pentanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,5-undecafluoro-, ammonium salt (ammonium PFPeS) according to domestic environmental hazard thresholds is presented below (EPHC, 2009; NICNAS, 2013b):

Persistence

Persistent (P). Based on the non-degradability of other perfluoroalkyl sulfonates, including PFBS and PFOS, all chemicals in this group are categorised as Persistent.

Bioaccumulation

Potassium PFPeS and ammonium PFPeS

Uncertain (Uncertain B). There is currently insufficient information to conclude whether the bioaccumulation potential of PFPeS is comparable to highly bioaccumulative long-chain homologues or to less bioaccumulative short-chain perfluoroalkyl sulfonates. The bioaccumulation potential of these chemicals is therefore categorised as Uncertain.

All remaining chemicals

Bioaccumulative (B). Based on the available bioaccumulation and biomagnification factors for PFHxS and PFOS, all chemicals in this group, except for potassium PFPeS and ammonium PFPeS, are categorised as Bioaccumulative.

Toxicity

Uncertain (Uncertain T). The primary toxicity concern for the chemicals in this group is chronic toxicity. There is currently insufficient information to conclude whether the long-term aquatic toxicity of the chemicals in this group is comparable to toxic long-chain homologues or to less toxic short-chain perfluoroalkyl sulfonates. The toxicity of these chemicals is therefore categorised as Uncertain.

Summary

Potassium PFPeS and ammonium PFPeS are categorised as:

P

Uncertain B

Uncertain T

Potassium PFHpS, ammonium PFHpS, diethanolammonium PFHpS, potassium PFHxS, ammonium PFHxS, diethanolammonium PFHxS and PFHxSF are categorised as:

P

B

Uncertain T

Risk Characterisation

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

Seven chemicals in this group have been identified as persistent and bioaccumulative substances. Chemicals which are persistent and bioaccumulative remain in the environment and accumulate in biota over an extended period of time, even if new emissions of the chemicals cease. These characteristics can result in very high internal concentrations in exposed organisms, which may cause long-term toxic effects that are not readily identified through standard testing protocols. Chemicals with these hazard characteristics are therefore considered to be of concern for the environment.

The bioaccumulation potential of the two C_5 perfluoroalkyl sulfonate chemicals in this group is uncertain. However, their close structural similarity to the bioaccumulative longer chain homologues and biomonitoring results which have consistently identified the perfluoropentanesulfonate anion in biota, indicate that these two chemicals should also be considered of concern for the environment.

Key Findings

The chemicals in this group are not expected to have significant current industrial use in Australia. However, if released to the environment, the chemicals in this group are expected to release surface-active perfluoroalkyl sulfonate anions. These perfluorinated anions are, or have potential to become, globally distributed pollutants. Further, these anions have been demonstrated to be, or may be, bioaccumulative. The persistence and bioaccumulation of perfluoroalkyl sulfonate anions increases the potential for chronic toxicity. However, no suitable chronic toxicity data are currently available for the chemicals in this group. Nevertheless, it is noted that the C_8 homologue, PFOS, can cause chronic intergenerational toxicity in fish.

All chemicals in this group have been categorised as persistent (P) according to domestic environmental hazard criteria. Most chemicals in this group have also been categorised as bioaccumulative (B), although for some chemicals insufficient data were available to determine a categorisation for this hazard characteristic. Insufficient data were available for all chemicals in this group to determine a reliable categorisation for toxicity.

In the absence of data which demonstrate a lower toxicity profile for C_5 to C_7 perfluoroalkyl sulfonate anions compared to PFOS, the chemicals in this group should be assumed to be of equivalent concern to direct precursors to PFOS in accordance with the action plan.

Recommendations

The chemicals in this group have been assessed as having the potential to give rise to adverse outcomes for the environment. These chemicals are currently listed on the Australian Inventory of Chemical Substances (AICS), and are available to be introduced into Australia without the requirement for assessment by NICNAS. Other chemicals with reduced potential for adverse outcomes are becoming available but, given the properties of these chemicals, their assessment as new chemicals under the *Industrial Chemicals (Notification and Assessment) Act 1989* (the ICNA Act) is still required to fully characterise the human health and the environmental risks associated with their use.

It is recommended that NICNAS consult with industry and other stakeholders to consider strategies, including regulatory mechanisms available under the ICNA Act, to encourage the use of safer chemistry.

The Action Plan

Insufficient data are available to demonstrate a lower toxicity profile for the chemicals in this group compared with direct precursors to PFOS. It is therefore recommended that the action plan currently contained in Appendix G of the Handbook for Notifiers should continue to be applied to the assessment of chemicals which degrade to PFHpS, PFHxS and PFPeS (NICNAS, 2015f).

Environmental Hazard Classification

In addition to the categorisation of environmental hazards according to domestic environmental thresholds presented above, the classification of the environmental hazards of 1-heptanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,7-pentadecafluoro-, potassium salt (potassium PFHpS); 1-heptanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,7-pentadecafluoro-, ammonium salt (ammonium PFHpS); 1-heptanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,7-pentadecafluoro-, compounds with 2,2′-iminobis[ethanol] (1:1) (diethanolammonium PFHpS); 1-hexanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,6-tridecafluoro-, potassium salt (potassium PFHxS); 1-hexanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,6-tridecafluoro-, ammonium salt (ammonium PFHxS); 1-hexanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,6-tridecafluoro-, compound with 2,2′-iminobis[ethanol] (1:1) (diethanolammonium PFHxS); 1-hexanesulfonyl fluoride, 1,1,2,2,3,3,4,4,5,5,6,6,6-tridecafluoro- (PFHxSF); 1-pentanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,5-undecafluoro-, potassium salt (potassium PFPeS); and 1-pentanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,5-undecafluoro-, ammonium salt (ammonium PFPeS) according to the third edition of the United Nations' Globally Harmonised System of Classification and Labelling of Chemicals (GHS) is presented below (UNECE, 2009):

Hazard	GHS Classification (Code)	Hazard Statement
Chronic Aquatic	Category 4 (H413)	May cause long lasting harmful effects to aquatic life

There are insufficient data available to categorise the acute aquatic hazards of the chemicals in this group. The long-term aquatic hazard of the chemicals in this group was classified as Chronic Category 4 ("safety net" classification), as the available evidence indicates that all perfluoroalkyl sulfonate anion components of these chemicals are highly persistent and are bioaccumulative, or there are significant concerns that they may be bioaccumulative, in aquatic ecosystems (UNECE, 2007).

In the environment, PFHxSF is expected to hydrolyse to PFHxS. The classification of PFHxSF should take into consideration the hazardous properties of this transformation product. Therefore, PFHxSF has been assigned the same classification as the salts of perfluorohexanesulfonic acid in this group.

Should additional data become available to suggest an alternate hazard classification is warranted for any of the chemicals in this group, these classifications may be revised as appropriate.

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Document 11

Environment Tier II Assessment for Direct Precursors to Perfluorooctanesulfonate (PFOS)

CAS Registry Numbers: 29457-72-5, 2795-39-3, 29081-56-9, 56773-42-3, 70225-14-8, 307-35-7.

Preface

This assessment was carried out under the National Industrial Chemicals Notification and Assessment Scheme (NICNAS). This scheme has been established by the *Industrial Chemicals (Notification and Assessment) Act 1989* (the Act), to aid in the protection of the Australian people and the environment by assessing the risks of industrial chemicals, providing information and making recommendations to promote their safe use.

As part of reforms regarding Existing Chemicals, NICNAS has implemented a new framework to address the human health and environmental impacts of previously unassessed industrial chemicals listed on the Australian Inventory of Chemical Substances (AICS).

The Inventory Multi-tiered Assessment and Prioritisation (IMAP) framework was developed with significant input from stakeholders. The framework provides a more rapid, flexible and transparent approach for the assessment of existing chemicals.

Stage One of this program, which is being undertaken over four years from 1 July 2012, is examining 3000 chemicals meeting characteristics identified by stakeholders as needing priority assessment. This includes chemicals for which NICNAS already holds exposure information, chemicals identified as a concern or for which regulatory action has been taken overseas, and chemicals detected in international studies analysing chemicals present in babies' umbilical cord blood.

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

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

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

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

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Acronyms & Abbreviations

Grouping Rationale

This Tier II assessment considers the environmental risks associated with the industrial uses of five salts of perfluorooctanesulfonic acid and perfluorooctane sulfonyl fluoride:

1-Octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, lithium salt (lithium PFOS)
1-Octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, potassium salt (potassium PFOS)
1-Octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, ammonium salt (ammonium PFOS)
Ethanaminium, *N*,*N*,*N*-triethyl-, salt with 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-1-octanesulfonic acid (1:1) (tetraethylammonium PFOS)
1-Octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, compound with 2,2′-iminobis[ethanol] (1:1) (diethanolammonium PFOS)
1-Octanesulfonyl fluoride, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro- (PFOSF)

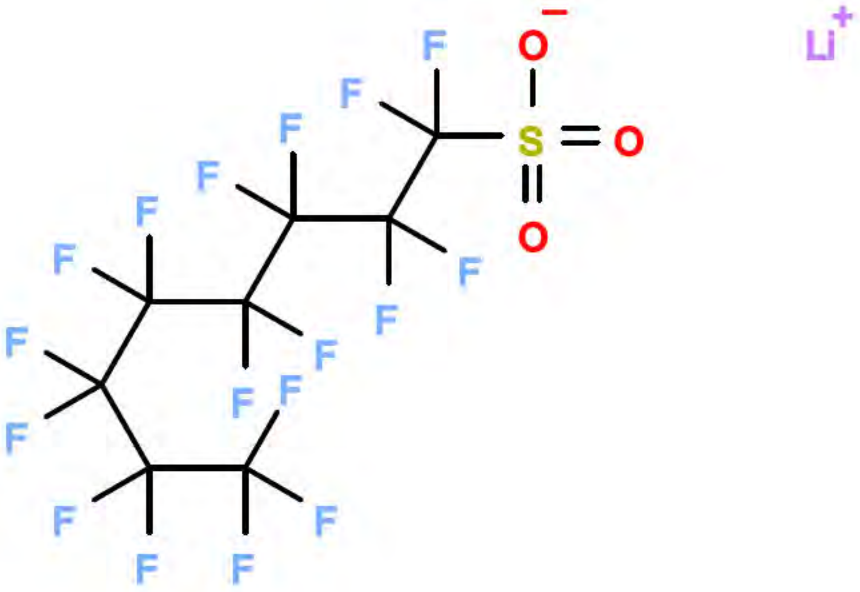
The chemicals in this group are long chain perfluorinated chemicals containing eight perfluorinated carbons terminated with a sulfonate or sulfonyl fluoride group. The risk assessment of these chemicals has been conducted as a group because all six substances are structurally related compounds each of which has the potential to hydrolyse and/or dissociate into the hazardous perfluorooctanesulfonate anion (PFOS).

The chemicals in this group have properties which make them useful for a wide range of specialised industrial applications. However, perfluorooctanesulfonic acid, its salts and perfluorooctane sulfonyl fluoride have all been identified as Persistent Organic Pollutants (POPs) under Annex B of the *Stockholm Convention on Persistent Organic Pollutants* (the Stockholm Convention). These substances are also listed on Annex III of the *Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade* (the Rotterdam Convention). These listings on two global conventions on chemicals have led to significant and evolving international restrictions on industrial uses of the chemicals in this group.

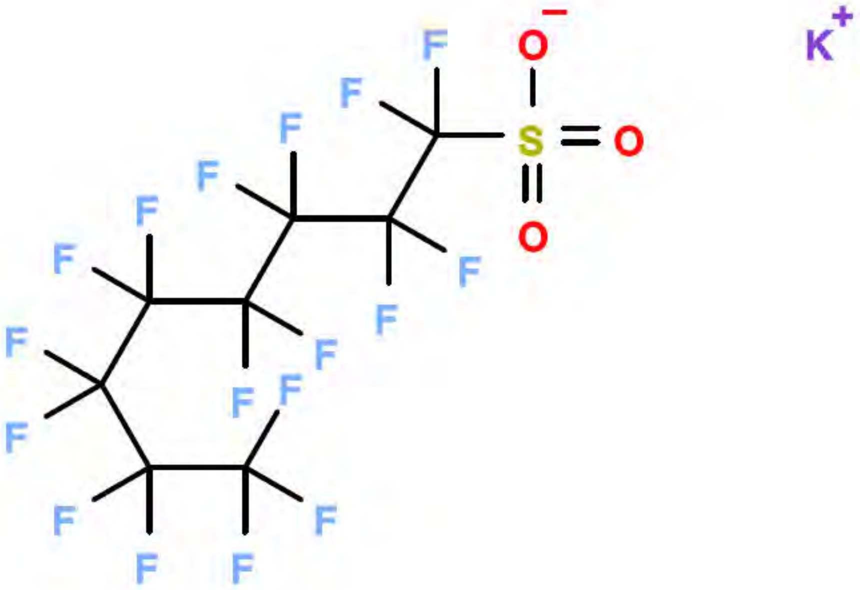
The assessment of these chemicals as a group also provides additional relevant information for the risk assessment of more complex derivatives of PFOS which may degrade to this perfluorinated anion in the environment. These more complex derivatives of PFOS have been assessed separately as the Indirect Precursors of Perfluorooctanesulfonate (PFOS) group.

Chemical Identity

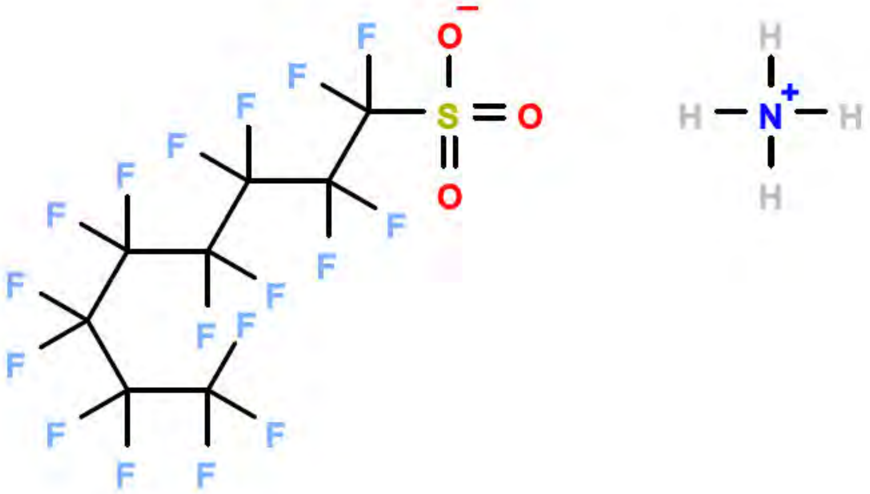
In this assessment, "PFOS" is used to denote the conjugate base anion of perfluorooctanesulfonic acid (i.e. the perfluorooctanesulfonate anion). However, it is noted that this descriptor is commonly used in relation to a range of substances which may easily form the anion in water, such as the parent acid and salts of the acid.

CAS RN	29457-72-5
Chemical Name	1-Octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, lithium salt
Synonyms	lithium PFOS lithium perfluorooctanesulfonate lithium heptadecafluorooctanesulfonate
Structural Formula	
Molecular Formula	$C_8F_{17}LiO_3S$
Molecular Weight (g/mol)	506.06
SMILES	C(F)(F)(C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)F)S(=O)(=O)[O-].[Li+]

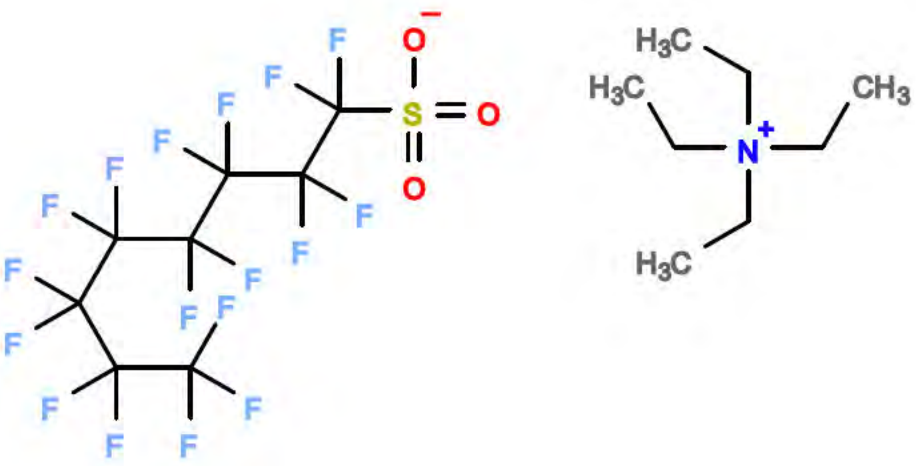
CAS RN	2795-39-3

Chemical Name	1-Octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, potassium salt
Synonyms	potassium PFOS potassium perfluorooctanesulfonate potassium heptadecafluorooctanesulfonate
Structural Formula	
Molecular Formula	$C_8F_{17}KO_3S$
Molecular Weight (g/mol)	538.22
SMILES	C(F)(F)(C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)F)S(=O)(=O)[O-].[K+]

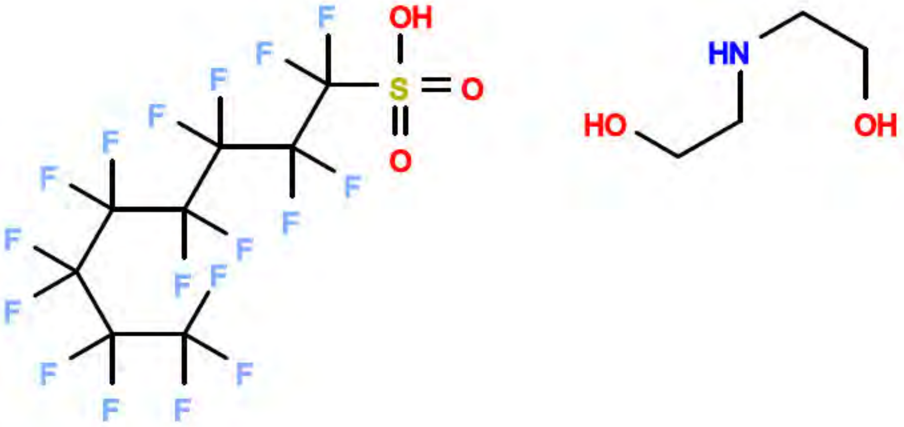
CAS RN	29081-56-9
Chemical Name	1-Octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, ammonium salt

Synonyms	ammonium PFOS ammonium perfluorooctanesulfonate ammonium heptadecafluorooctanesulfonate
Structural Formula	
Molecular Formula	$C_8H_4F_{17}NO_3S$
Molecular Weight (g/mol)	517.16
SMILES	C(F)(F)(C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)F)S(=O)(=O)[O-].[NH4+]

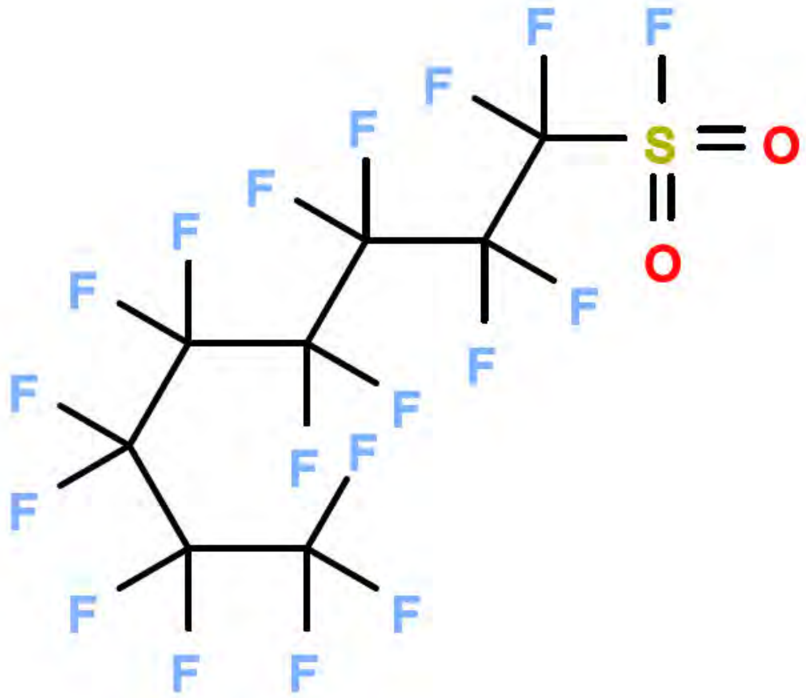
CAS RN	56773-42-3
Chemical Name	Ethanaminium, *N*,*N*,*N*-triethyl-, salt with 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-1-octanesulfonic acid (1:1)
Synonyms	tetraethylammonium PFOS tetraethylammonium perfluorooctanesulfonate tetraethylammonium heptadecafluorooctanesulfonate

Structural Formula	
Molecular Formula	$C_{16}H_{20}F_{17}NO_3S$
Molecular Weight (g/mol)	629.37
SMILES	C(F)(F)(C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)F)S(=O)(=O)[O-].C(C)[N+](CC)(CC)CC

CAS RN	70225-14-8
Chemical Name	1-Octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, compound with 2,2'-iminobis[ethanol] (1:1)
Synonyms	diethanolammonium PFOS diethanolammonium perfluorooctanesulfonate diethanolammonium heptadecafluorooctanesulfonate
Structural Formula	

	
Molecular Formula	$C_{12}H_{12}F_{17}NO_5S$
Molecular Weight (g/mol)	605.27
SMILES	C(F)(F)(C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)F)S(=O)(=O)O.C(O)CNCCO

CAS RN	307-35-7
Chemical Name	1-Octanesulfonyl fluoride, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-
Synonyms	PFOSF POSF perfluorooctanesulfonyl fluoride heptadecafluorooctanesulfonyl fluoride
Structural Formula	

	
Molecular Formula	$C_8F_{18}O_2S$
Molecular Weight (g/mol)	502.12
SMILES	C(F)(F)(C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)F)S(=O)(=O)F

Physical and Chemical Properties

Available physical and chemical property data for PFOSF and potassium PFOS are presented below (Lanners, 2010; OECD, 2002):

Chemical	PFOSF	potassium PFOS
Physical Form	Solid	Solid
Melting Point	> 25°C (exp.)	≥ 400°C (exp.)

Boiling Point	154°C (exp.)	Not measurable
Vapour Pressure	213 Pa at 20°C (exp.)	3.31×10^{-4} Pa at 20°C (exp.)
Water Solubility	0.29 mg/L (calc.)	570 mg/L (exp.)

The parent acid for the salts in this group, perfluorooctanesulfonic acid (CAS RN: 1763-23-1), is a very strong acid in water and is known to be surface-active (Gramstad and Haszeldine, 1957). A comprehensive range of relevant physical and chemical property data have been reported for the potassium salt of this strong acid. The water solubility data available for this salt show that it has moderate to high water solubility in pure water, but that the solubility in aqueous electrolytes (such as natural seawater) is significantly reduced. The octanol-water partition coefficient (K_{OW}) parameter is not considered to provide a reliable indicator of the partitioning behaviour of the surface-active perfluorinated anion in the environment and does not form part of the standard set of chemical property data for these salts (OECD, 2002).

Based on the data available for potassium PFOS, the other salts in this group are all expected to have moderate to high water solubility in pure water, low volatility, and significant surface activity.

The sulfonyl fluoride, PFOSF, is a neutral organic chemical of moderate molecular weight. It is estimated to be only slightly soluble in water. Based on the reported vapour pressure, it is considered to be a highly volatile substance. The hydrolysis of perfluoroalkyl sulfonyl fluorides is relatively slow in water under acid and neutral conditions, and the rate of hydrolysis decreases with increasing carbon chain length (Gramstad and Haszeldine, 1957). A half-life for hydrolysis of PFOSF was not identified. However, the half-life for hydrolysis of the short-chain homologue, perfluorobutanesulfonyl fluoride (CAS RN: 375-72-4), has been reported as 73 hours at pH 7 and 23°C (ECHA, 2015). A measured octanol-water partition coefficient (K_{OW}) value was not identified for PFOSF.

Import, Manufacture and Use

Australia

The five PFOS salts in this group include some of the more commercially important salts of perfluorooctanesulfonic acid used for industrial applications. These salts are often simply referred to as "PFOS" (UNEP, 2006). As the perfluorooctanesulfonate anion does not exist as a separate chemical substance, references to the introduction of "PFOS" in this section can include these commercially important PFOS salts. However, it is noted that quantities of introduced "PFOS" may also include more complex chemical substances which have a perfluorooctanesulfonyl moiety.

Available data indicate that 100 kg of PFOS was imported in bulk in 2013 by one importer. These imported chemicals were reformulated domestically for supply of PFOS-containing industrial products used in Australia. An additional business which imported pre-formulated products containing PFOS was also identified, and is estimated to import approximately 10 kg of these products per year. Further small imports of pre-formulated products containing PFOS were expected (Parliament of Australia, 2014). Recent import data show a decline in quantities of PFOS introduced compared to earlier years (NICNAS, 2013a; Parliament of Australia, 2014).

A survey conducted by NICNAS in 2008 found that the majority of products and mixtures containing PFOS imported into Australia in 2006 and 2007 were imported by the metal plating industry for use as mist suppressants (NICNAS, 2013a). The metal plating applications in Australia for PFOS relate in particular to chrome plating using hexavalent chromium (DSEWPaC, 2011). Other industries which imported products and mixtures containing PFOS in 2008 included the aviation industry where it is used in hydraulic fluid, and the photography and photolithography sectors where it is used as a surfactant (NICNAS, 2013a).

No Australian manufacture or export of PFOS or PFOS related chemicals is known (NICNAS, 2013a; Parliament of Australia, 2014).

It is noted that some of the chemicals in this group may be present in the environment due to historic use, or due to release from articles or the use of chemicals not covered by this assessment.

International

Due to their unique chemical properties, perfluorinated chemicals have been used for a wide range of specialised industrial applications. Nevertheless, use of PFOS containing chemicals has been declining globally. Concerns regarding persistence and bioaccumulation resulted in the largest global manufacturer of PFOS-based chemicals ceasing their production in 2002 (3M, 2014; OECD, 2002).

However, production by various additional companies increased shortly after the phase out by the main manufacturer. Production of PFOSF in China was estimated to have increased to at least 200 tonnes per annum by 2006 (US EPA, 2009b). An additional four countries were also reported to have manufactured PFOS related substances in 2005. Available data suggested a PFOSF production volume of approximately 70 tonnes, with production of tetraethylammonium PFOS and potassium PFOS reported in volumes up to approximately 30 tonnes and 20 tonnes, respectively. Between one and ten tonnes of lithium PFOS, and less than one tonne of ammonium PFOS were also reported to have been produced (OECD, 2006). A subsequent survey in 2008 indicated drastically reduced production of these chemicals. However, the response rate for this survey was very low and the data may not be representative (OECD, 2011).

Developed countries report use of PFOSF as a chemical intermediate, while the salts are used in photo-imaging, in the semiconductor industry, in metal plating (particularly chromium plating) and in fire-fighting foams (ECHA, 2014a; 2014b; UNEP, 2014e; 2014f). A wider range of uses are reported by developing countries, including use for chemically driven oil production, and use in carpets, leather and apparel, textiles and upholstery, paper and packaging, coatings and coating additives, and rubber and plastics (UNEP, 2014e; 2014f).

Tetraethylammonium PFOS is currently registered for use in the European Union at a volume between one and ten tonnes per annum (ECHA, 2014b).

Environmental Regulatory Status

Australia

Amendments made to regulation 11C(1) under the *Industrial Chemicals (Notification and Assessment) Regulations 1990* (Cwlth) in 2014 have resulted in controls being placed on the chemicals in this group (Australian Government Department of Health, 2014). The introduction or export of any chemical in this group is now prohibited unless approval is obtained from the NICNAS Director (Commonwealth of Australia, 1990).

The Australian Government Department of the Environment is currently undertaking a domestic treaty making process to consider ratification of the 2009 amendment to the Stockholm Convention, which includes the listing of perfluorooctanesulfonic acid, its salts and perfluorooctanesulfonyl fluoride (Australian Government Department of the Environment, 2011).

In 2008, a factsheet published by NICNAS recommended that PFOS-based chemicals be restricted to essential uses only, and that importers ensure that alternative chemicals are less toxic and not persistent in the environment (NICNAS, 2013a).

United Nations

All chemicals in this group are captured by the listing of perfluorooctanesulfonic acid, its salts and perfluorooctanesulfonyl fluoride on Annex B of the Stockholm Convention. The listing prohibits production and use of these chemicals for purposes other than those listed as acceptable purposes. Acceptable purposes include industrial use in photo-imaging, in formulation of photo-resist and anti-reflective coatings for semi-conductors, as an etching agent for compound semi-conductors and ceramic filters, in aviation hydraulic fluids, in closed-loop metal plating systems, in fire-fighting foam and in certain medical devices. In addition, a range of specific exemptions for additional uses are also available for a period of time while restrictions are phased in. The listing of these chemicals aims to reduce and ultimately eliminate use as suitable alternatives become available (UNEP, 2009).

Of the 193 member countries of the United Nations, 179 are party to the Stockholm Convention (UNEP, 2014d). Eighteen parties are yet to ratify the 2009 amendment, which includes the listing of perfluorooctanesulfonic acid, its salts and perfluorooctanesulfonyl fluoride. Australia, New Zealand and the USA are among this number (UNEP, 2014b).

In addition, the chemicals in this group are also captured by the listing of perfluorooctane sulfonic acid, perfluorooctanesulfonates, perfluorooctanesulfonamides and perfluorooctanesulfonyls on Annex III of the Rotterdam Convention (UNEP, 2014c). The Rotterdam Convention aims to facilitate sharing of chemical information to promote shared responsibility for the international trade of certain hazardous chemicals. Of the 193 United Nations member countries, 153 have ratified the Rotterdam Convention, including Australia. The European Union is also a party to the convention (UNEP, 2014a). Listing of the chemicals under the Convention was triggered by the severe restrictions placed on certain members of the group by Canada, the European Union and Japan (UNEP, 2013).

OECD

Perfluorooctanesulfonate and its salts were sponsored for assessment under the Cooperative Chemicals Assessment Programme (CoCAP) by the United Kingdom and the United States of America. The 34th Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides and Biotechnology in 2002 endorsed the hazard assessment, which found that PFOS and its salts were candidates for further work (OECD, 2002).

Canada

Perfluorooctanesulfonate and its salts are listed on the Virtual Elimination List under section 65 of the *Canadian Environmental Protection Act 1999* (Government of Canada, 2009). These chemicals must not be released to the environment at quantifiable levels.

Potassium PFOS, ammonium PFOS, tetraethylammonium PFOS and diethanolammonium PFOS are listed on the Canadian Domestic Substances List (DSL). During the Categorization of the DSL, all four chemicals were found to be Persistent (P) and Inherently Toxic to the Environment (iT_E). All were also found to be Bioaccumulative (B), except for tetraethylammonium PFOS, for which the bioaccumulation potential could not be determined (Environment Canada, 2013a). A screening assessment on PFOS, its salts and precursors was subsequently performed in 2006, and the amendment to the Virtual Elimination List was completed in 2009 (Environment Canada, 2006; Government of Canada, 2009). The remaining chemicals in the group, lithium PFOS and PFOSF, are not listed on the Canadian DSL (Environment Canada, 2013b).

European Union

The use of PFOS derivatives, including metal salts and PFOSF, is restricted under Commission Regulation No 850/2004 on Persistent Organic Pollutants (European Commission, 2010). These chemicals may only be used in select applications in electroplating systems, photolithography processes, photographic coatings, chromium plating, and aviation hydraulic fluids. Use is to be phased out as alternate substances or technologies become available.

Tetraethylammonium PFOS and PFOSF are currently registered for use in the European Union under the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) legislation (ECHA, 2014a; 2014b). All other chemicals in the group have been pre-registered, but have not yet undergone the full registration process (ECHA, 2014c).

United States of America

New uses of all chemicals in this group in the United States of America are prohibited without prior approval from the United States Environmental Protection Agency (US EPA) (United States Government, 2002; 2007). The US EPA understands that any existing uses of these chemicals are limited, highly technical uses for which there are no alternatives available, and have low environmental release (US EPA, 2014).

The US EPA published an action plan on long-chain perfluorinated chemicals, covering the chemicals in this group, in 2009. All chemicals were identified as persistent, bioaccumulative and toxic (US EPA, 2009b).

Japan

Perfluorooctanesulfonate and its salts, and PFOSF, have been designated as Class I Specified Chemicals Substances under *The Act on the Evaluation of Chemical Substances and Regulation of Their Manufacture, etc.* (NITE, 2014). Permission must be obtained from the Minister of Economy, Trade and Industry to manufacture, import or use these chemicals in most cases (Government of Japan, 2010).

Class I Specified Chemicals have been identified as persistent and highly bioaccumulative chemicals with risks of long-term toxicity to humans or predator animals at higher trophic levels (NITE, 2014).

Environmental Exposure

It is considered unlikely that PFOSF is used in Australia, as there is no known domestic manufacture of chemicals containing the perfluorooctanesulfonyl moiety. Based on the available information, if the salts in this group are introduced, they are most likely used as mist suppressants in metal plating, particularly chromium plating with hexavalent chromium. Minor use may occur in aviation hydraulic fluids and as surfactants in the photography and photolithography sectors.

Based on standard emission scenarios for industrial electroplating operations, some release of chemical substances used in electroplating to waste water and landfill can be expected (Environment Australia, 1999; OECD, 2004). Available international data suggest that, when used as a mist suppressant in chromium plating, mist suppressants containing PFOS are added to the bath solution and may be discharged to sewage treatment plants (STPs) after on-site waste water treatment. High concentrations of PFOS in STP sludge and effluent have been traced back to chromium plating plants in the USA (US EPA, 2009a). Assuming a similar emission pattern in Australia, and noting that STP sludge may be applied to land as biosolids, emissions of PFOS to environmental surface waters and soil may occur as a result of the use of chemicals in this group in domestic electroplating facilities.

The potassium, ammonium and lithium cations present as counterions in salts of this group are ubiquitous, naturally occurring inorganic species that are essential for many biological functions. The substituted ammonium compounds present as counterions in salts of this group are expected to be readily biodegradable with minimal excess toxicity. The environmental fate and effects of these cations are not further considered in this assessment.

Environmental Fate

Dissolution, Speciation and Partitioning

The salts in this group will dissolve to release the perfluorooctanesulfonic acid anion, which is expected to remain in the water compartment.

Perfluorooctanesulfonic acid is a very strong acid in water and under environmental conditions the acid will exist predominantly as the conjugate base anion (i.e. PFOS) (Brooke, et al., 2004). The salts of this very strong acid will dissociate into their constituent ions in water. The partitioning behaviour of the acid and its salts in the aquatic compartment will be influenced by the surface activity of the perfluorinated anion, which is the dominant species under environment conditions. Based on the comparatively high water solubility of simple PFOS salts, previous studies have concluded that the perfluorooctanesulfonic acid anion should be expected to remain in water if released to this compartment, unless adsorbed to particulate matter or assimilated by organisms. However, it is noted that traditional partitioning assumptions may not be appropriate for this perfluorinated anionic surfactant (OECD, 2002).

The neutral organic member of this group, PFOSF, is less soluble in water than the PFOS salts and highly volatile. Based on these properties, this chemical should be expected to experience enhanced partitioning to the atmosphere, with less partitioning to water.

Degradation

The PFOS component of the chemicals in this group is highly resistant to degradation.

The perfluorooctanesulfonate anion is exceptionally persistent in the environment. Various studies have demonstrated that PFOS is resistant to hydrolysis, aqueous photolysis, and biodegradation. The hydrolysis half life of PFOS has been estimated to be more than 41 years, and there is no indication of direct or indirect photolysis in water (UNEP, 2006). No biodegradation has been observed in ready biodegradability studies conducted according to OECD Test Guideline (TG) 301C (OECD, 2002).

In the environment, PFOSF hydrolyses to release PFOS. The rate of hydrolysis is unknown, but is expected to be slow (Aberlin and Bunton, 1970; Martin, et al., 2010). In the atmosphere, PFOSF has also been found to be resistant to photodegradation and atmospheric hydroxyl radical attack. The chemical has an atmospheric half-life of 3.7 years, with eventual degradation hypothesised to release PFOS (Environment Canada, 2006; UNEP, 2006).

Bioaccumulation

The PFOS component of the chemicals in this group is highly bioaccumulative.

Perfluorinated chemicals have been observed to bioaccumulate by binding to proteins in plasma and liver, rather than the more conventional partitioning to fatty tissue. Studies measuring the concentration of the PFOS in plasma and liver have found bioconcentration factors (BCFs) of 3100 and 2900, respectively, in the fish *Onchorhynchus mykiss*. An additional study found the whole-fish kinetic BCF for the fish *Lepomis macrochirus* to be 2796 (UNEP, 2006). Further, available data also suggest PFOS has a high biomagnification potential. Biomagnification factors (BMFs) based on measured concentrations in wildlife have been estimated to range between 22 and 4000 (UNEP, 2006).

Transport

The PFOS component of the chemicals in this group is a globally distributed pollutant.

As a highly volatile and persistent chemical, PFOSF has properties which indicate strong potential for long-range transport. However, limited data are available to evaluate this.

Numerous studies have identified PFOS in various locations worldwide. The PFOS anion has been measured in marine mammals in remote regions far from anthropogenic emission sources, including Alaska, the Northern Baltic Sea, Arctic and Sable Islands. Additional studies have found PFOS in fish in the Northern Pacific Ocean, and in Antarctica (OECD, 2002). More recent data indicate the presence of PFOS in the Atlantic and Arctic Oceans (Benskin, et al., 2012). The global distribution of PFOS as an environmental contaminant has been difficult to rationalise in terms of conventional long range transport pathways. It has been hypothesised that such distribution may occur through transport in surface water or oceanic currents, transport of volatile PFOS precursors (such as PFOSF), adsorption to particles and/or through living organisms (UNEP, 2006).

Predicted Environmental Concentration (PEC)

A PEC was not calculated for the chemicals in this group, as a significant body of high quality environmental monitoring data for PFOS are available from multiple sites around the world.

A study of six cities in the USA, published in 2001, found STP effluent PFOS concentrations between 0.04-5.29 µg/L and STP sludge concentrations up to 3120 µg/kg (dry weight). In drinking water, PFOS concentrations were found up to 0.06 µg/L, while concentrations in surface waters were found to range up to 0.14 µg/L. Concentrations in sediment were found to be up to 1.13 µg/kg (dry weight). Higher concentrations were found in landfill leachate, with a maximum reported value of 53 µg/L (OECD, 2002). It is noted that the study included four cities with fluorochemical industries, and therefore likely represent a worse-case scenario.

More recently, a review published in 2009 cited data from 2006-8 which suggested surface water concentrations of PFOS in the USA, Japan, Italy, Germany and China were generally less than 0.2 µg/L. However, one study was reported to have found concentrations up to 0.7 µg/L in South Korea, and the United Kingdom Environment Agency was reported to have found concentrations up to 33.9 µg/L at certain targeted sites (Rumsby, et al., 2009). An Australian study of perfluorinated compounds in drinking water published in 2011 reported PFOS concentrations up to 0.02 µg/L, with the perfluorinated anion being detected in half of the 62 samples (Thompson, et al., 2011).

It is noted that many sites globally, including in Australia, have been identified as experiencing high PFOS contamination due to the use of fire fighting foams containing the perfluorinated anion (eg. CRCCARE, 2013; SERDP, 2014). However, fire fighting foam containing PFOS is no longer used for training purposes in Australia, and alternate products are being sought as existing stocks of PFOS based foams are replaced (NICNAS, 2013a).

Environmental Effects

Effects on Aquatic Life

The chemicals in this group will release PFOS in the environment and this is expected to have long-term toxic effects across many organisms.

Toxicity of PFOSF

The following measured median effective concentration (EC50) and median lethal concentration (LC50) values for model organisms across two trophic levels were reported in the REACH Registration Dossier or by Hekster et al. (ECHA, 2014a; Hekster, et al., 2002). No details regarding use of a solubiliser or observation of insoluble matter are provided:

Taxon	Endpoint	Method
Fish	96 h LC50 > 1000 mg/L	Experimental *Pimephales promelas* (Fathead minnow)
Invertebrates	48 h EC50 > 100 mg/L	Experimental *Daphnia magna* (Water flea) OECD TG 202 Nominal concentrations

Toxicity of PFOS salts

The following measured EC50, LC50 and median inhibitory concentration (IC50) values for model organisms across three trophic levels for (a) lithium PFOS and (b) potassium PFOS were reported in the OECD Hazard Assessment of PFOS and its Salts, and the Risk Profile on Perfluorooctane Sulfonate prepared for the Stockholm Convention POPs Review Committee (OECD, 2002; UNEP, 2006). All organisms are freshwater species except for the marine species *Mysidopsis bahia*:

Taxon	Endpoint	Method
Fish	(a) 96 h LC50 = 4.7 mg/L	Experimental *Pimephales promelas* (Fathead minnow) Static Nominal concentrations

Taxon	Endpoint	Method
Invertebrates	(b) 48 h EC50 = 27 mg/L	Experimental *Daphnia magna* (Water flea) OECD TG (1981); static Nominal concentrations
	(b) 96 h LC50 = 3.6 mg/L	Experimental *Mysidopsis bahia* (Mysid shrimp) OPPTS 850.1035; static Measured concentrations
Algae	(b) 96 h IC50 = 48.2 mg/L	Experimental *Pseudokirchneriella subcapitata* (Green algae)

The following no-observed-effect-concentration (NOEC) values for model organisms across three aquatic trophic levels for potassium PFOS were reported in the OECD Hazard Assessment of PFOS and its Salts or the Risk Profile on Perfluorooctane Sulfonate prepared for the Stockholm Convention POPs Review Committee (OECD, 2002; UNEP, 2006). All organisms are freshwater species except the marine species *M. bahia*:

Taxon	Endpoint	Method
Fish	42 d NOEC = 0.3 mg/L	Experimental *Pimephales promelas* (Fathead minnow) OECD TG 210; flow-through Measured concentrations Reduced growth and survival
Invertebrates	28 d NOEC = 7 mg/L	Experimental *Daphnia magna* (Water flea) OECD TG (1981); semi-static Nominal concentrations Reproductive toxicity observed
	35 d NOEC = 0.25 mg/L	Experimental *Mysidopsis bahia* (Mysid shrimp) OPPTS 850.1350; flow-through

Taxon	Endpoint	Method
		Measured concentrations Reproductive toxicity observed
Algae	96 h NOEC = 5.3 mg/L	Experimental *Pseudokirchneriella subcapitata* (Green algae)

While standard ecotoxicity testing results suggest moderate chronic toxicity, a growing number of non-standard tests have identified high chronic aquatic toxicity as demonstrated by a range of intergenerational effects. Ji et al. (2008) found no significant effects in regards to mortality or condition factors in exposed adult *Oryzias latipes* (Japanese medaka) at PFOS concentrations of 1 mg/L for 14 days. However, cumulative mortality of the offspring after 100 days was significantly increased when the parent had been exposed to 0.01 mg/L PFOS. Mortality increased further when the F_1 generation were also exposed to the perfluorinated anion (Ji, et al., 2008). In a similar study, Du et al. (2009) found significantly higher rates of malformations in the F_1 generation when maternal fish (*Danio rerio*) were exposed to 0.05 mg/L PFOS for 70 days. No deformed larvae survived (Du, et al., 2009). These studies provide emerging evidence to demonstrate high chronic toxic of PFOS in aquatic organisms that are not detected by standard test protocols.

Effects on Sediment-Dwelling Life

The chemicals in this group will release PFOS in the environment and this is expected to have long-term toxic effects in sediment-dwelling organisms.

Toxicity of PFOSF

No suitable data were available to evaluate the effects of PFOSF on sediment-dwelling organisms.

Toxicity of PFOS salts

The toxicity of PFOS to the midge *Chrionomus tentans* has been studied, with a 10 d NOEC of 0.0491 mg/L obtained. Reduced growth and survival rates were observed (UNEP, 2006).

Effects on Terrestrial Life

The chemicals in this group will release PFOS in the environment, which is expected to have long-term toxic effects in terrestrial organisms

Toxicity of PFOS salts

The majority of toxicity testing on terrestrial organisms has been conducted on model organisms to evaluate the toxicity of PFOS in humans. Further information on these studies can be found in the IMAP Tier II Human Health Assessment of Perfluorooctanesulfonic Acid and its Salts (NICNAS, 2015).

Predicted No-Effect Concentration (PNEC)

Use of the chemicals in this group will result in the environmental release of the perfluorooctanesulfonic acid anion, which is highly bioaccumulative and persistent. These two hazard characteristics combined have the potential to result in a range of long term effects on organisms exposed to these chemicals which cannot be readily identified through standard ecotoxicity tests. For such chemicals, it is not currently possible to estimate a safe exposure concentration using standard extrapolation methods based on laboratory screening levels tests. Predicted no-effects concentrations have therefore not been derived for the chemicals in this group.

Categorisation of Environmental Hazard

The categorisation of the environmental hazards of 1-octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, lithium salt (lithium PFOS); 1-octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, potassium salt (potassium PFOS); 1-octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, ammonium salt (ammonium PFOS); ethanaminium, *N*,*N*,*N*-triethyl-, salt with 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-1-octanesulfonic acid (1:1) (tetraethylammonium PFOS); 1-octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, compound with 2,2′-iminobis[ethanol] (1:1) (diethanolammonium PFOS); and 1-octanesulfonyl fluoride, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro- (PFOSF) according to domestic environmental hazard thresholds is presented below (EPHC, 2009; NICNAS, 2013b):

Persistence

Persistent (P). Based on the non-degradability of PFOS, and the expectation that all chemicals in this group will release PFOS in the environment, all chemicals in this group are categorised as Persistent.

Bioaccumulation

Bioaccumulative (B). Based on the bioaccumulation properties of PFOS, and the expectation that all chemicals in this group will release PFOS in the environment, all chemicals in this group are categorised as Bioaccumulative.

Toxicity

Toxic (T). Based on the long-term toxicity of PFOS, and the expectation that all chemicals in this group will release PFOS in the environment, all chemicals in this group are categorised as Toxic.

Summary

1-Octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, lithium salt; 1-octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, potassium salt; 1-octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, ammonium salt; ethanaminium, *N*,*N*,*N*-triethyl-, salt with 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-1-octanesulfonic acid (1:1); and 1-octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, compound with 2,2′-iminobis[ethanol] (1:1); and 1-octanesulfonyl fluoride, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro- are categorised as:

- P
- B
- T

Risk Characterisation

The chemicals in this group have been identified as PBT substances. It is not currently possible to derive a safe environmental exposure level for such chemicals and it is therefore not appropriate to characterise the environmental risks for these chemicals in terms of a risk quotient.

Due to their persistence, PBT chemicals have the potential to become widely dispersed environmental contaminants. Once in the environment, persistent chemicals that are also highly bioaccumulative pose an increased risk of accumulating in exposed organisms and of causing adverse effects. They may also biomagnify through the food chain resulting in very high internal concentrations, especially in top predators. Importantly, it is difficult or impossible to reverse the adverse effects of PBT chemicals once they have been released to the environment. As a result, these chemicals are considered to be of high concern for the environment.

Persistent organic pollutants are chemicals that are very persistent, very bioaccumulative, toxic, and have potential to undergo long-range transport. The Stockholm Convention identifies POPs and aims to reduce or eliminate the environmental release of POP substances. It is noted that all chemicals in this group are listed on Annex B of the Stockholm Convention (UNEP, 2001).

Key Findings

The chemicals in this group have been identified under Annex B of the *Stockholm Convention on Persistent Organic Pollutants* and Annex III of the *Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade* due to their potential to release PFOS to the environment. The PFOS component of the chemicals in this group is recognised globally as an exceptionally persistent, highly bioaccumulative and toxic chemical.

This assessment establishes that 1-octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, lithium salt (lithium PFOS); 1-octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, potassium salt (potassium PFOS); 1-octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, ammonium salt (ammonium PFOS); ethanaminium, *N*,*N*,*N*-triethyl-, salt with 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-1-octanesulfonic acid (1:1) (tetraethylammonium PFOS); and 1-octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, compound with 2,2′-iminobis[ethanol] (1:1) (diethanolammonium PFOS); and 1-octanesulfonyl fluoride, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro- (PFOSF) as PBT substances according to domestic environmental hazard criteria. Therefore, these chemicals are considered to be high concern substances.

The salts in this group are expected to have small scale uses in Australia, with the majority used in chromium plating using hexavalent chromium. Based on international information and standard emission scenarios, release of PFOS to the environment may occur as a result of domestic uses of salts of perfluorooctanesulfonic acid as mist suppressants in industrial electroplating operations. However, domestic use of the chemicals in this group is declining, and is expected to continue to decline as restrictions on use increase in accordance with international treaties and regulatory actions. A Tier III assessment under the IMAP framework may be warranted should there be any changes in the trends in uses and import volumes.

Recommendations

It is recommended that the Australian Government Department of the Environment note the risks posed by industrial use of these chemicals, as outlined in this assessment, under the current domestic treaty-making process which is considering ratification of the 2009 amendment to the *Stockholm Convention on Persistent Organic Pollutants.*

As currently recommended by NICNAS, PFOS based chemicals should be restricted to only essential uses, and importers should ensure alternative chemicals are less toxic and not persistent in the environment.

Environmental Hazard Classification

In addition to the categorisation of environmental hazards according to domestic environmental thresholds presented above, the classification of the environmental hazards of 1-octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, lithium salt (lithium PFOS); 1-octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, potassium salt (potassium PFOS); 1-octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, ammonium salt (ammonium PFOS); ethanaminium, *N*,*N*,*N*-triethyl-, salt with 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-1-octanesulfonic acid (1:1) (tetraethylammonium PFOS); and 1-octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, compound with 2,2′-iminobis[ethanol] (1:1) (diethanolammonium PFOS); and 1-octanesulfonyl fluoride, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro- (PFOSF) according to the third edition of the United Nations' Globally Harmonised System of Classification and Labelling of Chemicals (GHS) is presented below (UNECE, 2009):

Hazard	GHS Classification (Code)	Hazard Statement
Acute Aquatic	Category 2 (H401)	Toxic to aquatic life
Chronic Aquatic	Category 1 (H410)	Very toxic to aquatic life with long lasting effects

The classification of the hazards posed by these chemicals has been performed based on the ecotoxicity data presented in this assessment. Acute data demonstrate aquatic toxicity in the range of 1-10 mg/L. Adequate chronic toxicity data were considered to be available for these chemicals, which demonstrate toxicity less than 0.1 mg/L. The chronic categorisation of these chemicals also considered the non-rapid ultimate degradation of these substances and their very high bioaccumulation potential in aquatic ecosystems (UNECE, 2007).

In the environment, PFOSF is expected to hydrolyse to PFOS. The classification of PFOSF should take into consideration the hazardous properties of this transformation product. Therefore, PFOSF has been assigned the same classifications as the salts of perfluorooctanesulfonic acid in this group, based on its potential to cause similarly hazardous environmental effects as other direct precursors to PFOS in the environment.

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Document 12

Environment Tier II Assessment for Indirect Precursors to Perfluorooctanoic acid (PFOA)

CAS Registry Numbers: 678-39-7, 1996-88-9, 93705-98-7, 68187-42-8, 53515-73-4.

Preface

This assessment was carried out under the National Industrial Chemicals Notification and Assessment Scheme (NICNAS). This scheme has been established by the *Industrial Chemicals (Notification and Assessment) Act 1989* (the Act), to aid in the protection of the Australian people and the environment by assessing the risks of industrial chemicals, providing information and making recommendations to promote their safe use.

As part of reforms regarding Existing Chemicals, NICNAS has implemented a new framework to address the human health and environmental impacts of previously unassessed industrial chemicals listed on the Australian Inventory of Chemical Substances (AICS).

The Inventory Multi-tiered Assessment and Prioritisation (IMAP) framework was developed with significant input from stakeholders. The framework provides a more rapid, flexible and transparent approach for the assessment of existing chemicals.

Stage One of this program, which is being undertaken over four years from 1 July 2012, is examining 3000 chemicals meeting characteristics identified by stakeholders as needing priority assessment. This includes chemicals for which NICNAS already holds exposure information, chemicals identified as a concern or for which regulatory action has been taken overseas, and chemicals detected in international studies analysing chemicals present in babies' umbilical cord blood.

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

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

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

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

Disclaimer

NICNAS has made every effort to assure the quality of information available in this report. However, before relying on it for a specific purpose, users should obtain advice relevant to their particular circumstances. This report has been prepared by NICNAS using a range of sources, including information from databases maintained by third parties, which include data supplied by industry. NICNAS has not verified and cannot guarantee the correctness of all information obtained from those databases. Reproduction or further distribution of this information may be subject to copyright protection. Use of this information without obtaining the permission from the owner(s) of the respective information might violate the rights of the owner. NICNAS does not take any responsibility whatsoever for any copyright or other infringements that may be caused by using this information.

Acronyms & Abbreviations

Grouping Rationale

This Tier II assessment considers the environmental risks associated with the industrial uses of five indirect precursors to perfluorooctanoic acid (PFOA):

1-Decanol, 3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,10-heptadecafluoro- (8:2 FTOH)
2-Propenoic acid, 2-methyl-, 3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,10-heptadecafluorodecyl ester (8:2 FTMAC)
2-Propenoic acid, 2-methyl-, 3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,10-heptadecafluorodecyl ester, polymer with methyl 2-methyl propenoate
Propanamide, 3-[(.gamma.-.omega.-perfluoro-C4-10-alkyl)thio] derivatives
2-Propenoic acid, 2-methyl-, 2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-pentadecafluorooctyl ester, polymer with 2-propenoic acid

Four of the chemicals in this group are structurally related compounds in that they all contain a chain of eight perfluorinated carbons linked to another group through an ethylene unit. The fifth chemical is a polymer with side chains that contain seven perfluorinated carbons linked through a methylene unit to a methacrylate co-polymer backbone. The chemicals in this group are of concern because they have the potential to degrade to environmentally persistent perfluorinated carboxylic acids, including PFOA (OECD, 2007).

NICNAS has developed an action plan to assess and manage chemicals which may degrade to perfluorinated carboxylic acids, perfluoroalkyl sulfonates and similar chemicals, which can be found in Appendix G of the Handbook for Notifiers on the NICNAS website (NICNAS, 2015a). The primary assumption outlined in this action plan is that chemicals with a perfluorinated carbon chain terminated with an alkyl or aryl group will degrade to form a mix of perfluorocarboxylic acids, with both the original perfluorinated chain length and one less perfluorinated carbon atom.

Most chemicals in this group contain a chain of eight perfluorinated carbons linked to another functional group or polymer chain through an ethylene unit. Under the action plan, these chemicals are assumed to have the potential to degrade either to perfluorononanoic acid or PFOA. However, PFOA is expected to be the major product of environmental biodegradation of these precursors (Butt, et al., 2014). The ester linkage in the fifth chemical is assumed to be susceptible to hydrolysis, which would release a fluoroalcohol that has the potential to be oxidised to PFOA (OECD, 2007). Therefore, potential environmental degradation of the chemicals in this group to PFOA is the principal focus of this assessment.

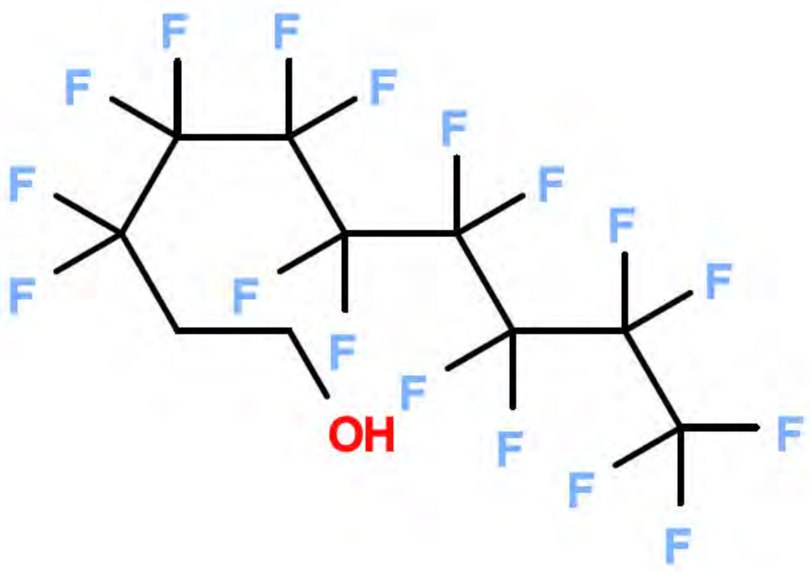
Perfluorooctanoic acid has been identified as a Persistent, Bioaccumulative and Toxic (PBT) chemical (NICNAS, 2015b). Long-chain perfluoroalkyl and polyfluoroalkyl substances such as PFOA and perfluorooctanesulfonic acid are of concern internationally due to their PBT properties. Perfluorooctanesulfonic acid and certain related substances containing the perfluorooctane sulfonate (PFOS) moiety have recently been identified as Persistent Organic Pollutants under Annex B of *Stockholm Convention on Persistent Organic Pollutants*. These substances are also listed on Annex III of the *Rotterdam Convention on the Prior Informed Consent Procedure for*

Certain Hazardous Chemicals and Pesticides in International Trade. Further information on perfluorooctanesulfonic acid and related substances can be found in the Environment Tier II Assessment of the Direct Precursors to Perfluorooctanesulfonate (PFOS) group (see NICNAS, 2015c).

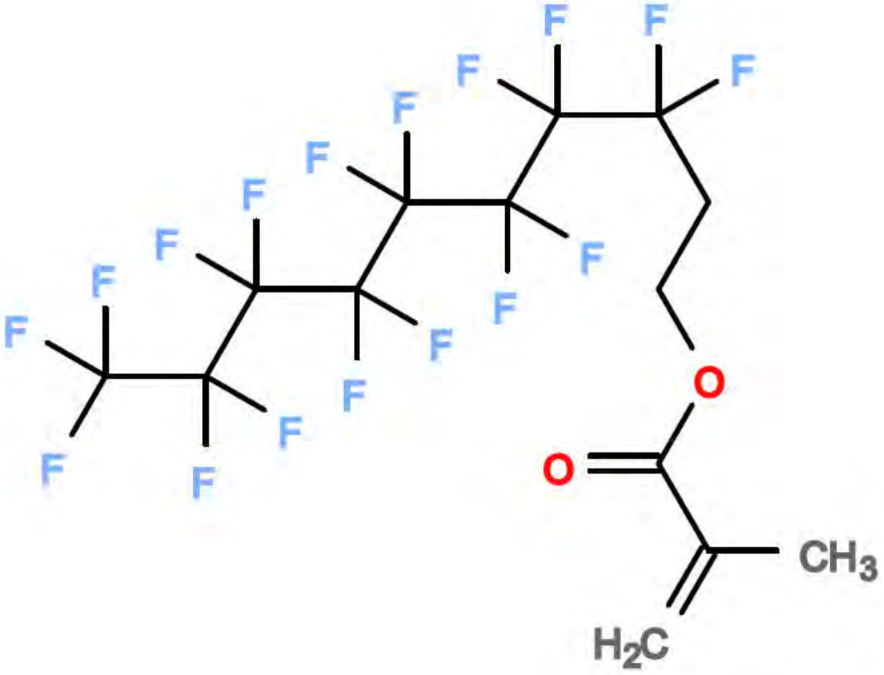
The degradation of PFOA is very slow compared with its rate of formation from degradation of the precursors and PFOA will be the final degradant from multiple precursors. Therefore, the amount of PFOA in the environment (general or local) is expected to be higher than that of any of the precursors. It will therefore be assumed for the purposes of this assessment that the primary risk posed by the chemicals in this group results from release of PFOA to the environment. The IMAP-Environment Tier II assessment for Perfluorooctanoic Acid and its Direct Precursors (see NICNAS, 2015b) has been used as a reference assessment.

Chemical Identity

In this assessment, "PFOA" is used to denote perfluorooctanoic acid and its conjugate base (i.e. the perfluorooctanoate anion) (Buck, et al., 2011).

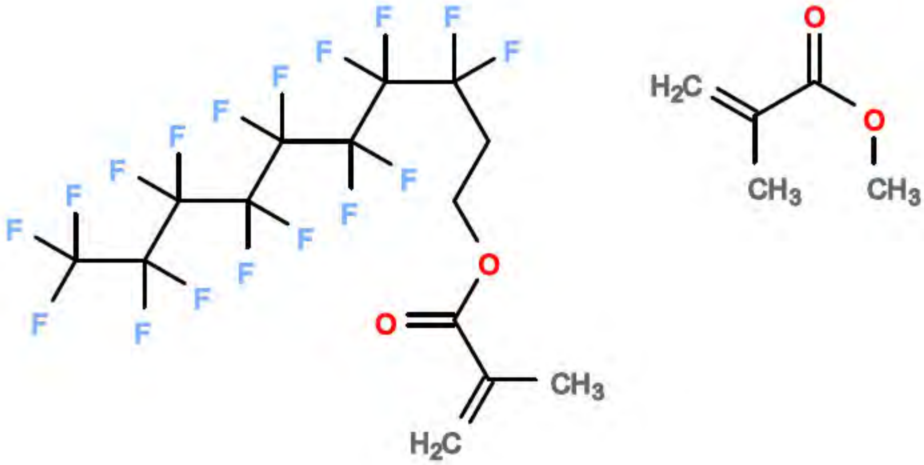
CAS RN	678-39-7
Chemical Name	1-Decanol, 3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,10-heptadecafluoro-
Synonyms	8:2 FTOH 8:2 fluorotelomer alcohol 2-(perfluorooctyl)ethanol 1,1,2,2-tetrahydroheptadecafluorodecanol
Structural Formula	

Molecular Formula	$C_{10}H_5F_{17}O$
Molecular Weight (g/mol)	464.12
SMILES	C(F)(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)CCO

CAS RN	1996-88-9
Chemical Name	2-Propenoic acid, 2-methyl-, 3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,10-heptadecafluorodecyl ester
Synonyms	8:2 FTMAC 8:2 fluorotelomer methacrylate 2-(perfluorooctyl)ethyl methacrylate
Structural Formula	
Molecular Formula	$C_{14}H_9F_{17}O_2$

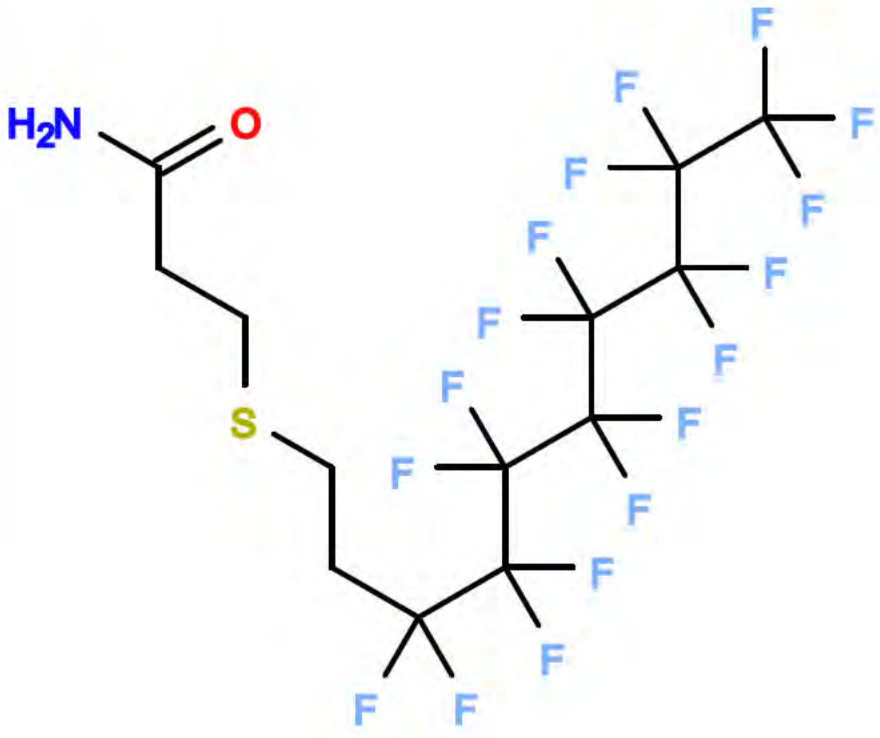
Molecular Weight (g/mol)	532.19
SMILES	C(F)(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F) C(F)(F)C(F)(F)CCOC(=O)C(=C)C

The substance represented by CAS RN 93705-98-7 is a polymer. The constituent monomers of this side-chain fluorinated co-polymer are presented below. Due to the typically variable size and structure of polymer molecules, the molecular formula and molecular weight are not presented.

CAS RN	93705-98-7
Chemical Name	2-Propenoic acid, 2-methyl-, 3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,10-heptadecafluorodecyl ester, polymer with methyl 2-methyl propenoate
Synonyms	8:2 fluorotelomer methacrylate, polymer with methyl methacrylate
Structural Formula	
SMILES	C(F)(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F) C(F)(F)C(F)(F)CCOC(=O)C(=C)C.COC(=O)C(=C)C

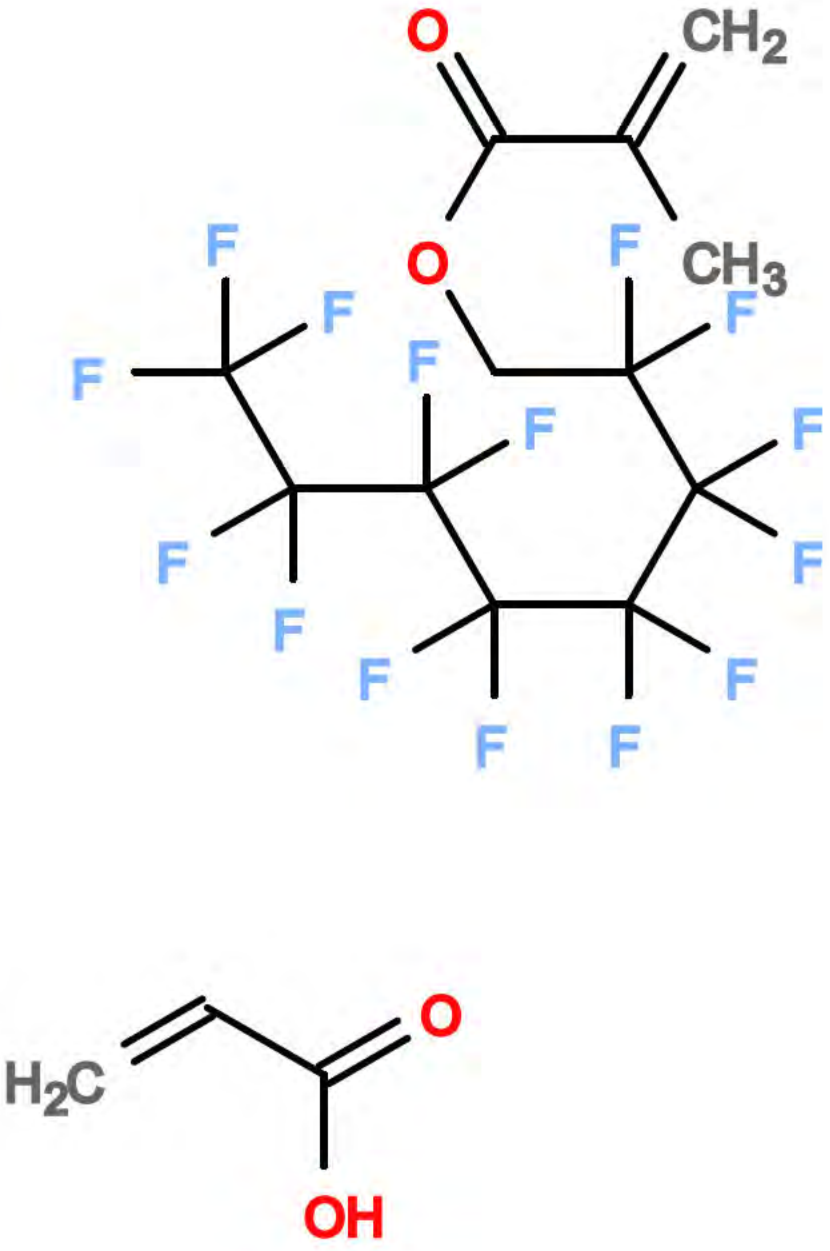
The substance represented by CAS RN 68187-42-8 is expected to be a mixture of discrete chemicals. Representative chemical identity information is provided below. However, it should be noted that this substance is expected to include a mixture of chemicals with perfluorinated chains between two and eight carbons in length (OECD, 2007).

CAS RN	68187-42-8

Chemical Name	Propanamide, 3-[(.gamma.-.omega.-perfluoro-C4-10-alkyl)thio] derivatives
Synonyms	3-[(.gamma.-.omega.-perfluoro-C4-10-alkyl)thio] propanamide derivatives
Representative Structural Formula	
Representative Molecular Formula	$C_{13}H_{10}F_{17}NOS$
Representative Molecular Weight (g/mol)	551.26
Representative SMILES	C(F)(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F) C(F)(F)C(F)(F)CCSCCC(=O)N

The substance represented by CAS RN 53515-73-4 is a polymer. The constituent monomers of this side-chain fluorinated co-polymer are presented below. Due to the typically variable size and structure of polymer molecules, the molecular formula and molecular weight are not presented.

CAS RN	53515-73-4

Chemical Name	2-Propenoic acid, 2-methyl-, 2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-pentadecafluorooctyl ester, polymer with 2-propenoic acid
Synonyms	7:1 fluoroalcohol methacrylate, polymer with acrylic acid
Structural Formula	
SMILES	C(F)(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F) C(F)(F)COC(=O)C(=C)C.OC(=O)C(=C)

Physical and Chemical Properties

Available physical and chemical property data for 8:2 FTOH are presented below (ECHA, 2014a):

Physical Form	Solid
Vapour Pressure	31 Pa at 25°C (exp.)
Water Solubility	0.14 mg/L (exp.)

The 8:2 telomer alcohol is reported to be a white waxy solid under ambient conditions. The substance is volatile under ambient conditions, although the measured vapour pressure is reported to be dependent on the method employed. For example, some measurements provide a vapour pressure as high as 254 Pa at 25°C (ECHA, 2014a).

No experimental physical and chemical property data were located for the remaining chemicals in this group. However, the chemicals in this group will have a wide range of physical and chemical properties given differences in chemical structure. For example, the polymers in this group are not expected to be volatile. In contrast, 8:2 FTMAC is expected to be volatile based on its structural similarity to 8:2 FTOH. This is supported by a reported measured vapour pressure of 8.6 Pa for the analogue chemical 6:2 FTMAC (CAS RN 2144-53-8) (ENVIRON, 2014). The propanamide may also experience a degree of volatility.

The reported measured water solubility values available for 8:2 FTOH and 6:2 FTMAC (0.378 mg/L) (ENVIRON, 2014) indicate that some chemicals in this group will have slight solubility in water. When considered alongside the volatility of these chemicals, these data suggest that the lower molecular weight discrete chemicals in this group will be highly volatile from water (calculated Henry's law constants = 102 800 and 9833 Pa m^3/mol for 8:2 FTOH and 6:2 FTMAC, respectively).

Import, Manufacture and Use

Australia

In July 2006, NICNAS collected information on manufacture, importation and uses of perfluorinated chemicals including PFOA-related substances and products/mixtures containing these substances for the calendar years 2004 and 2005. Information provided to NICNAS indicated that no PFOA related chemicals are manufactured in Australia. An antifoam product containing <10% of a PFOA-related chemical (CAS RN not specified) was imported in 2005 for use in a dyeing process with sulfur dyes. The total quantity imported was approximately 10 kg (NICNAS, 2013).

It is noted that the chemicals in this group may be present in the environment due to historic use, release from pre-treated articles imported into Australia, or the use of other chemicals. However, release from these uses is beyond the scope of this assessment.

International

Two chemicals in this group are reported to have use in the manufacture of other fluorochemicals. The reactive methacrylate, 8:2 FTMAC, is used as a monomer in the production of polymers with fluorinated side-chains. The 8:2 fluorotelomer alcohol is used mainly in the manufacture of fluorinated surfactants and surface protection products (Buck, et al., 2011). The latter chemical may be found in final products as residual unreacted starting material, in some cases at measurable levels (ECHA, 2013; SFT, 2007).

Polymers with fluorinated side-chains, and surface protection products, are used to treat surfaces to repel water, grease, dirt and oil. Commonly treated articles include sports and outdoor clothing, home textiles and upholstery, carpets and medical garments. These chemicals can also be used in products such as paints and lacquers, and waxes and polishes (ECHA, 2014a).

The fluorotelomer based chemicals also have commercial uses in non-stick coatings on cookware, in anti-foam formulations, in silicone rubber products as well as uses in analytical laboratories and in the automotive, mechanical, aerospace, chemical, electrical, medical, and building and construction industries (OECD, 2006; 2008).

In 2007, 8:2 FTOH was reported to be produced at a volume greater than 1,000 tonnes per annum in at least one OECD member country (OECD, 2013). Results from an OECD survey conducted in 2009 found 8:2 FTOH and 8:2 FTMAC to be produced in two countries. However, the response rate for this survey was very low and data may not be representative (OECD, 2011).

No specific volume or production data were located for the polymers in this group. However, it was recently estimated that approximately 1000 tonnes of PFOA-related substances for textile and leather treatment are introduced per annum in the European Union. It was further estimated that between 1000 and 10 000 tonnes of PFOA-related substances were additionally imported into the European Union contained in textile articles (ECHA, 2014a).

No use data were identified for the propanamide.

Environmental Regulatory Status

Australia

In 2007, a factsheet published by NICNAS recommended that industry seek alternatives to PFOA and chemicals that may degrade to PFOA, and ultimately aim to phase out use of these substances (NICNAS, 2013).

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).

OECD

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

One chemical in this group (8:2 FTOH) has been identified as a High Production Volume (HPV) chemical by the OECD, indicating that more than 1000 tonnes of the chemical are produced per year in at least one member country (OECD, 2013).

The OECD has been leading an international collaboration on the scientific assessment of, and surveys of, perfluorinated chemicals. Since July 2000, Australia has been actively involved in this work through NICNAS.

Canada

Substances with a perfluoroheptyl or perfluorooctyl moiety are listed under Schedule 1 (the Toxic Substances List) of the *Canadian Environmental Protection Act 1999* (CEPA 1999) (Environment Canada, 2010; Government of Canada, 2013). A proposal to prohibit the import, manufacture and use of these chemicals has been released, and is expected to be finalised by January 2016 (Environment Canada, 2012).

During the Categorization of the Canadian Domestic Substances List (DSL), 8:2 FTOH was found to be Persistent (P), Bioaccumulative (B) and Inherently Toxic to the Environment (iT_E). Three further chemicals in this group were categorised, with the propanamide and 7:1 fluoroalcohol methacrylate co-polymer both found to be P. The propanamide was found to be not B and not iT_E, while the polymer was found to be iT_E. The bioaccumulation potential of the polymer could not be determined. Similarly, the bioaccumulation potential and inherent toxicity of 8:2 FTMAC could not be determined. However, 8:2 FTMAC was found to be not P (Environment Canada, 2013b). The remaining polymer in this group is not listed on the DSL (Environment Canada, 2013a).

European Union

In October 2014, a proposal to restrict the use of PFOA, its salts, and substances that may degrade to PFOA under the European Union Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) legislation was published. The proposal covers manufacture, sale and use of PFOA, its salts, and substances that may degrade to PFOA if present in concentrations greater than two parts per billion (ECHA, 2014a; 2015b).

Three chemicals in this group (8:2 FTOH, 8:2 FTMAC and the propanamide) have been pre-registered for use in the European Union under the REACH legislation (ECHA, 2015a). However, no chemicals in this group have undergone the full registration process (ECHA, 2014b).

United States of America

In January 2006, the United States Environmental Protection Agency (US EPA) launched a global PFOA stewardship program. The eight major companies that manufacture fluoropolymers and telomers committed to reduce facility emissions of all PFOA, PFOA precursors and related chemicals by 95% by no later than 2015 (compared to 2000 baseline) (US EPA, 2009).

All chemicals in this group, except for the 8:2 methacrylate polymer, are listed on the inventory of chemicals manufactured or processed in the USA, as published under the *Toxic Substances Control Act 1976* (TSCA) (US EPA, 2014). The United States Environmental Protection Agency (US EPA) proposed a new Significant New Activity Rule for these chemicals in January 2015. Under the Rule, approval must be sought for new uses of these chemicals. The US EPA understands that existing uses of these chemicals will be phased out by December 2015 under a voluntary stewardship programme (US EPA, 2015).

The US EPA published an action plan on long-chain perfluorinated chemicals, covering the chemicals in this group, in 2009. All chemicals were identified as persistent, bioaccumulative and toxic (US EPA, 2009).

Environmental Exposure

Based on international data, the polymers in this group may have use in a wide range of applications in Australia. Release to the environment may occur during the use and disposal of the chemical, including the use and disposal of products containing the chemical, and that of articles treated with commercial and domestic surface treatment products. Both 8:2 FTOH and 8:2 FTMAC are not expected to have industrial use in Australia, as data collected by NICNAS indicate that PFOA related chemicals are not manufactured in Australia (NICNAS, 2013). Any use of the propanamide is expected to be limited.

The environmental degradant of primary concern for the chemicals in this group is PFOA. This chemical is purely of anthropogenic origin and has been identified as a PBT substance (NICNAS, 2015b).

Multiple studies have demonstrated the potential for 8:2 FTOH to degrade to PFOA. Biotransformation of 8:2 FTOH to PFOA has been proposed to occur by a mechanism which involves the defluorination of one perfluorinated carbon atom. Atmospheric degradation of 8:2 FTOH occurs through oxidation by chlorine or hydroxyl radicals, resulting in a so-called "unzipping" cycle that forms perfluorinated carboxylic acids of various lengths, including PFOA (Butt, et al., 2014; De Voogt, 2010; Dinglasan, et al., 2004; Ellis, et al., 2004).

A number of recent studies have further demonstrated potential for biodegradation of 8:2 acrylate and methacrylate fluorotelomer derivatives (including commercial polymers with acrylate–linked fluorotelomer side-chains) in soil and water to yield PFOA (Butt, et al., 2014; Rankin, et al., 2014; Royer, et al., 2014; Washington, et al., 2015). Hydrolysis of the ester bond is expected to release 8:2 FTOH, which degrades to PFOA as described above. Less data are available for the 7:1 fluoroalcohol methacrylate co-polymer, although degradation to PFOA has been assumed to occur (OECD, 2007).

Monitoring data have identified 8:2 FTOH and PFOA in the environment. The volatile 8:2 FTOH is routinely found in outdoor air, with detections made in locations remote as Antarctica and in the livers of Arctic polar bears (Del Vento, et al., 2012; OECD, 2008). Typical outdoor air concentrations in regions more densely populated by humans appear to range between 5 and 275 picograms per cubic metre (pg/m^3) (Barber, et al., 2007 ; Jahnke, et al., 2007). Concurrently, international studies have identified PFOA in various media, including surface and drinking waters. In Australia, PFOA has been identified in the Parramatta and Brisbane river catchments. The chemical has been found in Australian drinking water at concentrations up to 9.7 nanograms per litre (ng/L) (NICNAS, 2015b).

It is noted that there are multiple potential sources of 8:2 FTOH and PFOA in the environment including past industrial use of other fluorinated chemicals contaminated with these substances, use in articles, or from the use of other fluorinated chemicals which degrade to these substances in the environment.

Environmental Effects

The currently available ecotoxicity data for PFOA are summarised in the IMAP-Environment Tier II assessment for Perfluorooctanoic Acid (PFOA) and its Direct Precursors. Data currently available for PFOA indicate low acute aquatic toxicity (median lethal/effective concentration values > 300 mg/L) and chronic aquatic toxicity (no-observed-effect concentration values ≥ 12.5 mg/L) in standard ecotoxicity tests. However, data from a growing number of non-standard ecotoxicity tests have identified intergenerational toxicity in the F_1 generation when both the parent and offspring are exposed to concentrations as low as 0.1 mg/L (NICNAS, 2015b).

The chemicals in this group contain a range of functional groups and moieties which are correlated with acute toxic effects in aquatic organisms. However, these possible effects have not been considered in this assessment, as the primary risk posed by the chemicals in this group is assumed to result from the cumulative release of PFOA into the environment.

Categorisation of Environmental Hazard

Insufficient data are presented in this assessment to categorise the chemicals in this group according to domestic environment hazard thresholds (EPHC, 2009).

It is noted that direct precursors to PFOA are categorised as Persistent, Bioaccumulative and Toxic (PBT) substances according to domestic environmental hazard criteria (NICNAS, 2015b).

Risk Characterisation

The chemicals in this group may degrade to a PBT substance. It is not currently possible to derive a safe environmental exposure level for such chemicals and it is therefore not appropriate to characterise the environment risks for these chemicals in terms of a risk quotient.

The recalcitrant degradant assumed to be formed from each of the chemicals in this group (PFOA) has been identified as a PBT chemical. Due to their persistence, PBT chemicals have the potential to become widely dispersed environmental contaminants. Once in the environment, persistent chemicals that are also highly bioaccumulative pose an increased risk of accumulating in exposed organisms and of causing adverse effects. They may also biomagnify through the food chain resulting in very high internal concentrations, especially in top predators. Importantly, it is difficult or impossible to reverse the adverse effects of PBT chemicals once they have been released to the environment.

Key Findings

Based on international data, the polymers in this group may have current industrial use in a wide range of formulations in Australia, including paints, polishes, and surface treatments for various textile products. The remaining chemicals in this group are not expected to be significantly used in Australia. Some chemicals, especially 8:2 FTOH, may be present as residual contaminants in chemical products containing the polymers and in pre-treated articles. However, the risks posed by these contaminants have not been considered in this assessment.

Available data indicate that chemicals in this group have the potential to degrade to PFOA. Therefore, the principal risk posed by the chemicals in this group if emitted to the environment is assumed to result from cumulative releases of the degradation product, PFOA. This perfluorinated chemical has been identified as a PBT chemical and is therefore of high concern to the environment.

The chemicals in this group have not been categorised according to domestic environmental hazard criteria. This finding does not indicate a lack of potential hazard for some parent chemicals in this group, but rather a lack of suitable data in this assessment to characterise these hazards for each individual chemical.

It is noted that significant volumes of the chemicals in this group may also be imported into Australia as a component of finished articles. However, release from these articles and the associated environmental risks are beyond the scope of this assessment.

The assessment of the risks from these chemicals to human health, including public health, has been considered in the IMAP-Human Health Tier II assessment for Indirect Precursors to Perfluorooctanoic Acid (PFOA) (NICNAS, 2015d).

Recommendations

The chemicals in this group have been assessed as having the potential to give rise to adverse outcomes for the environment and public health. These chemicals are currently listed on the Australian Inventory of Chemical Substances (AICS), and are available to be introduced into Australia without any further assessment by NICNAS. Other chemicals with reduced potential for adverse outcomes are becoming available but, given the properties of these chemicals, their assessment as new chemicals under the *Industrial Chemicals (Notification and Assessment) Act 1989* (the ICNA Act) is still required to fully characterise the human health and the environmental risks associated with their use.

It is recommended that NICNAS consult with industry and other stakeholders to consider strategies, including regulatory mechanisms available under the ICNA Act, to encourage the use of safer chemistry.

Environmental Hazard Classification

Insufficient data are presented in this assessment to classify the aquatic hazards of chemicals in this group according to the third edition of the United Nations' Globally Harmonised System of Classification and Labelling of Chemicals (GHS) (UNECE, 2009).

It is noted that direct precursors to PFOA have been classified as Chronic Aquatic Category 1 (H410) under the GHS (NICNAS, 2015b).

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Australian Government
Department of Health

Per- and Poly-Fluoroalkyl Substances (PFAS)

HEALTH EFFECTS AND EXPOSURE PATHWAYS

What are PFAS?

Per- and Poly-fluoroalkyl Substances (PFAS) are a group of man-made chemicals that have been widely used since the 1950s in household and industrial products that resist heat, oil, stains, grease and water. This included non-stick cookware, food packaging, stain protection applications to fabric, furniture and carpet, and fire-fighting foams. Since 1970, firefighting foams containing PFAS were once used extensively in Australia and elsewhere due to their effectiveness in fighting liquid fuel fires. There are many types of PFAS, with the best known examples being perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA).

PFAS have emerged as compounds of interest as they can travel long distances through soil and water and can get into groundwater. These substances don't break down in the environment and can accumulate in animals, including humans. However, in humans, there is no consistent evidence that PFAS cause any specific illnesses, including cancer.

More recently, PFAS have been found to have contaminated sites where there has been historical use of fire-fighting foams. In Australia, state and territory regulatory authorities have taken action to reduce the environmental and potential public health risks at sites where there is confirmed contamination with these chemicals.

How can PFAS affect people's health?

In humans, there is no consistent evidence that PFAS cause any specific illnesses, including cancer.

However, since these chemicals remain in humans and the environment for many years, it is recommended that as a precaution human exposure to PFAS be minimised.

Research into potential health effects of PFAS is ongoing around the world. To date there is not enough information available to definitively say what, if any, health effects may be caused by exposure to PFAS.

As part of the Australian Government's response to PFAS contamination at Defence sites, the Australian National University has been commissioned to undertake an epidemiological study (a health study that looks at patterns of disease in a population) of two sites in Australia—Williamtown in New South Wales and Oakey in Queensland. This study is expected to add to understanding the effects of PFAS on health in this population.

In studies where large doses of PFAS are given to laboratory animals, possible links with effects on the immune system, liver, reproduction, development and benign (non-cancer) tumours have been identified. However, studies in people have not provided definitive results. PFAS behaves differently in the bodies of animals compared to humans, so effects shown in one animal may not mean the same thing happens in humans.

Possible links between PFOS and PFOA exposure and several health effects have been reported in epidemiological studies around the world. However, many of these findings have been inconsistent, with some studies identifying problems and others finding none. Where changes in the body have been noticed, it has been unclear if they would have a significant effect on the health of the person. Organisations that study toxic chemicals have concluded that it is not possible to identify any definite links due to problems with study designs and contradictions in study results.

What is the evidence telling us so far?

A number of health conditions have been highlighted for further research based on the evidence so far. These conditions have been mentioned by international health agencies as being possibly linked to PFAS exposure.

An explanation of the evidence available on some of the highlighted health conditions is described below.

Does PFAS exposure affect cholesterol levels?

A number of studies show a possible link between PFAS exposure and increased blood cholesterol. Because of the design of the studies, it can't be determined if PFAS causes the increased blood cholesterol changes or if other factors are involved, such as diet.

Does PFAS exposure cause cancer?

There is no conclusive evidence that exposure to PFAS causes cancer in humans. Some studies have shown a possible link between prostate, kidney, and testicular cancers in workers involved in the manufacture of PFAS. In these studies other potential cancer-causing factors such as smoking were not considered. There are also some studies that have not shown a link between cancers and PFAS exposure.

Studies in rats have shown an increase in some types of thyroid cancer. The results are inconsistent, as rates of cancer only increased with one level of exposure. Higher and lower levels of exposure did not increase cancer in the rats.

Does PFAS exposure affect the immune system?

Some studies in animals show that immune problems may be associated with PFAS exposure. Other studies show that there isn't an effect. Some organisations are saying that PFAS is presumed to be an immune hazard to humans based on these animal studies. In studies that do show an effect on the immune system in certain people, there is no evidence that these people get more infections.

One study has shown that there is a possible link between PFAS and ulcerative colitis, but no other autoimmune disease. The evidence so far does not show any link between PFAS and autoimmune problems.

Does PFAS exposure cause problems during pregnancy?

There is currently no consistent evidence that exposure to PFAS causes poor outcomes in pregnant women or their babies. There are some studies that show a lower birth weight in babies born to mothers with higher levels of PFAS in their blood. Because of the design of these studies, it is not possible to know if PFAS causes this change or if other factors are involved. There are also some studies that have not shown a link between a lower birth weight and PFAS exposure during pregnancy.

What treatment is available?

There is no practical treatment available to remove PFAS from the body. As a precaution, ongoing exposure should be minimised in all people.

Do I need to be tested for PFAS?

Individual blood testing for PFAS is not currently helpful to manage any current medical problems or to predict future health problems. All Australians are expected to have some amount of PFAS in their blood due to the wide range of things it has been used for. A broad range of levels would be expected in all communities due to background exposure. There is no level of PFAS that is considered 'normal' or 'abnormal'.

How can people be exposed to PFAS?

People can be exposed to PFAS in their workplace if they are involved in the manufacture or use of PFAS. Outside of the workplace, exposure to PFAS can occur from food, water (ground and surface water) and various consumer products.

A number of sites in Australia, including the RAAF Base Williamtown and the Army Aviation Centre Oakey, are being investigated because firefighting foams containing PFAS were used there in the past. People have potentially been exposed at these sites by drinking contaminated water.

There is currently no consistent evidence that exposure to PFAS causes poor outcomes in pregnant women or their babies. However, unborn babies can be exposed to PFAS through the PFAS in their mother's body. PFAS can also be transferred to babies through breast milk.

Should I continue to breastfeed?

Yes. While some PFAS have been detected in breast milk, the proven health benefits associated with breastfeeding outweigh any potential health risk to an infant from the transfer of PFAS through breast milk. Breastfeeding mothers living in or around sites contaminated with PFAS do not need to stop breastfeeding.

How long does it take for PFAS to leave my system?

The time it takes for PFAS to be excreted from the body is the same for adults and children. In humans, studies suggest that the half-life of PFAS could range from two to nine years.

How can I reduce my exposure to PFAS?

Reducing PFAS exposure will mean avoiding contaminated sources. The available data from the 24th Australian Total Diet Survey suggests that dietary exposure to PFAS from the general food supply is likely to be low as the majority of samples in studies reported in Australia and elsewhere did not detect these chemicals in testing.

Advice will change depending on where you live and food sources from contaminated areas may have higher levels of PFAS. If you live on or near a contaminated site, please follow the most current advice provided by your state or territory government or the Department of Defence. This information will be will be available on their websites.

Further information

People can feel anxious or concerned for many reasons when PFAS contamination is found in their area. Help is available from your GP or mental health professional. Your GP can also follow up any physical health concerns that you may have.

The Department of Health

For further information regarding the Australian Government Department of Health's response to PFAS contamination, including health advice published by the Australian Health Protection Principal Committee (AHPPC) and its subcommittee enHealth, please visit the Department of Health website (health.gov.au/pfas).

Alternatively you can contact the Department of Health by phone on 1800 941 180 or by email: health.PFAS@health.gov.au.

The Department of Defence

For further information regarding the Department of Defence's response to PFAS contamination and site specific information please visit the Department of Defence website (defence.gov.au/id/pfospfoa/default.asp).

Per- and poly fluoroalkyl substances - overview

What is the PFAS problem?

- Per- and poly-fluoroalkyl substances (PFAS) are a group of manufactured chemicals (numbering over 3,000 chemicals) that have been widely used globally, since the 1950s. The substances most commonly referred to are PFOS[1], PFOA[2] and PFHxS[3].
- PFAS have become a focus of concern: they persist in the environment (no known natural process breaks them down); they easily migrate many kilometres from source; and they bio-accumulate.
- PFAS have been used in the manufacture of household and industrial products because they resist heat, stains, grease and water. Examples of PFAS uses (past and present) include: consumer products (carpets, leather, upholstery, apparel, cosmetics, sunscreens, paper, packaging, rubber, plastics, electronic parts for printers and copiers), insecticides, metal plating, plastics etching, fire-fighting foam, photographic materials, aviation hydraulic fluid and medical devices.

Fire Fighting Foams

- Both the public and private sectors worldwide have used PFAS fire-fighting foams for over 30 years. Although this accounts for less than 5% of PFAS used in Australia, it is a significant source of dispersal of contamination, in the vicinity of fire training grounds (particularly Defence bases, airports and Rural Fire Service grounds).
- Because PFAS have been used so extensively, many sites (airports, firefighting training, petrochemical facilities, industrial areas and landfills) are likely to be contaminated.

Health Concerns and government advice

- While we know that PFAS can persist in humans, animals and the environment for a long time, we cannot conclusively say that PFAS exposure is harmful to human health. Unlike in most animals, the human body gets rid of PFAS slowly, with a half-life measured in years.
- Most Australians have measurable levels of PFAS in their blood, although background levels have been declining. People working in or living near contaminated sites may have higher levels than the general public.
- Direct ingestion of contaminated drinking water (usually bore water) is the pathway of greatest concern.
- Australian governments are issuing precautionary advice to minimise exposure, while research is ongoing to determine whether there are human health impacts of exposure.
- To support risk assessments undertaken as part of PFAS site investigations, the Commonwealth Department of Health commissioned a report by Food Standards Australia New Zealand (FSANZ) entitled *Perfluorinated Chemicals in Food*, published in April 2017. FSANZ determined maximum acceptable amounts of the three main PFASs of concern that an individual could consume on a daily basis for an entire lifetime, without risk to health. These are expressed as Total Daily Intakes (TDIs).

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[1] PFOS = Perfluorooctane sulfonate, also known as perfluorooctane sulfonic acid.

[2] PFOA = Perfluorooctanoic acid.

[3] PFHxS = Perfluorohexane sulfonate, also known as perfluorohexane sulfonic acid.

- In this report, FSANZ recommended that there is no need for specific regulations, testing, and maximum PFAS levels for the general food supply.
- In order to exceed the TDIs FSANZ recommended for these chemicals, a person would have to consume all their food, all the time, from a contaminated site.
- As there are no regulated Maximum Levels for any PFAS in any foods in Australia or overseas, there are currently no restrictions on domestic or international trade in agricultural or aquacultural products.

Scope of the problem

- The Commonwealth has identified potential Commonwealth managed sites with PFAS use or stockpiles and there are many hundreds (if not thousands) of state owned and private sites of concern. Defence is currently investigating 23 sites and Air Services 20 Civilian Airports.
- Of greatest concern for the Commonwealth are those sites like Williamtown, NSW and Oakey, Qld and Katherine in the NT that have a high incidence of PFAS dispersal with an underground aquifer used for drinking water and irrigation of crops and livestock. However, if people have access to uncontaminated reticulated water (e.g. near metropolitan and large regional airports) the exposure pathways for humans is greatly reduced.

Communication and Community Expectations

- The focus of media attention over the last two years has been on Oakey and Williamtown. More recently, media attention has focused on Katherine, NT.
- There is generally a poor understanding in the community about the risks associated with exposure to PFAS and sensational reporting by media – especially the Newcastle Herald and some talk show hosts including Alan Jones and John Laws. ABC’s Four Corners program on PFAS contamination (9 October 2017) brought the issue to a level of national awareness.
- There have been ongoing concerns in the community about peoples’ health and the values of their properties associated with fear of the contamination plumes around Oakey and Williamtown.

Government responses

- The Australian Government has established a PFAS Taskforce in PM&C, which has improved Commonwealth cooperation across departments and collaboration with states and territories.
- Internationally, most of the action in response to PFAS is centred on investigations and the provision of alternative supplies of water (US and Sweden)– there has been no movement by any other governments to buy back land or provide significant compensation, although in the US there has been some successful litigation, notably:
    - A 3,000 plus member class action against Dupont settled for USD$607 million. (Settled with no admission of liability as part of a company merger)
    - Some individual payouts against manufacturers of several million dollars – (based on uncontested health claims).
- The Australian Government is responding to PFAS contamination in a range of ways including: investigating contaminated sites, developing an intergovernmental agreement with states and territories, considering new policies, supporting further research, liaising with industry bodies, and responding to two class actions before the Federal Court.

Whole of Australian Government achievements in 2017

During 2017, the **PFAS Taskforce** chaired the PFAS Interdepartmental Committee (IDC), which includes representation from thirteen Australian Government agencies. Over the last twelve months, the Taskforce and IDC agencies have worked together (and in close collaboration with states and territories where appropriate) to deliver the following with lead agency identified:

- A draft Intergovernmental Agreement on a National Framework for Responding to PFAS Contamination (the National Framework), to be taken to COAG for endorsement in early 2018 (Taskforce – see below for more information);
- The PFAS National Environmental Management Plan due for endorsement by Environment Ministers by end of 2017 (Department of the Environment and Energy);
- Working on management options for a phase out of PFOS and related compounds as part of Government's decision-making on ratifying amendments to the Stockholm Convention on Persistent Organic Pollutants (Department of the Environment and Energy);
- A National Remediation Research Program (Taskforce, Department of Defence, Department of Industry, Australian Research Council) announced on 14 December;
- A National Research Program into the Human Health Effects of Prolonged Exposure to PFAS, informed by public submissions and an Expert Panel (Department of Health);
- An epidemiological study, linked with a voluntary blood testing program, focusing on people who lived and worked in Williamtown, Oakey and Katherine (Department of Health);
- A comprehensive report by FSANZ[4] that provides Health Based Guidance Values for site investigations, a dietary exposure assessment, and risk management advice for authorities investigating PFAS contamination (Department of Health);
- A Whole of Australian Government Approach for Assessing and Responding to PFAS Contamination to ensure a consistent approach across Commonwealth agencies (Taskforce);
- Whole of Australian Government Communication and Engagement Guidelines (Taskforce);
- Ongoing preliminary and detailed site investigations on 23 Defence Sites and 20 Air Services sites (Department of Defence and Airservices Australia);
- Numerous community engagement and consultation activities (Departments of Defence, Infrastructure and Regional Development, Health, Environment and Energy, Agriculture and Water Resources, Human Services, and Airservices Australia);
- A stocktake of sites currently owned, managed or leased by the Commonwealth, and identified stockpiles of PFAS containing products (Taskforce, with input from all Commonwealth agencies); and
- Engagement with the banking sector, property valuers, insurance representatives, and local government, to provide information on PFAS contamination and Government responses (Taskforce).

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[4] FSANZ = Food Standards Australia New Zealand. FSANZ develops and sets food standards which become part of food law in the Australian states and territories, and New Zealand.

Document 15

PFAS 101

Overview

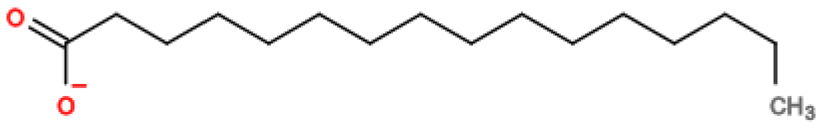
- Context
- Nomenclature
- Types of PFAS (incl. properties and uses)
- Environmental concentrations
- Bioaccumulation
- Environmental toxicity
- Human health impacts

Context

- There are over 3000 PFAS, which have been in use for over 50 years.
- Since the early 2000s, evidence of adverse impacts has emerged – especially for PFOS and PFOA.
  - But not all PFAS have been shown to have impacts
- The historic uses of PFAS have resulted in widespread environmental contamination.

Chemistry basics

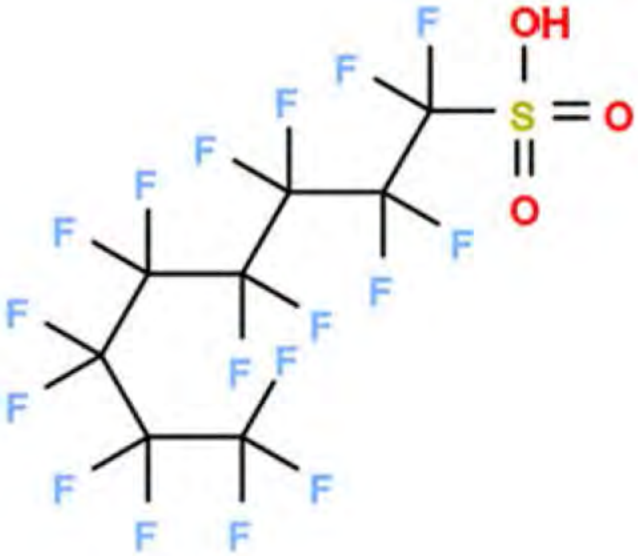
- Organic chemicals (i.e. not metals) have a carbon backbone.
- Backbones are cyclic or linear (alkyl).
- A carbon atom will have four bonds. When not specified, the bonds are with a hydrogen atom.



Per- and poly-fluoro

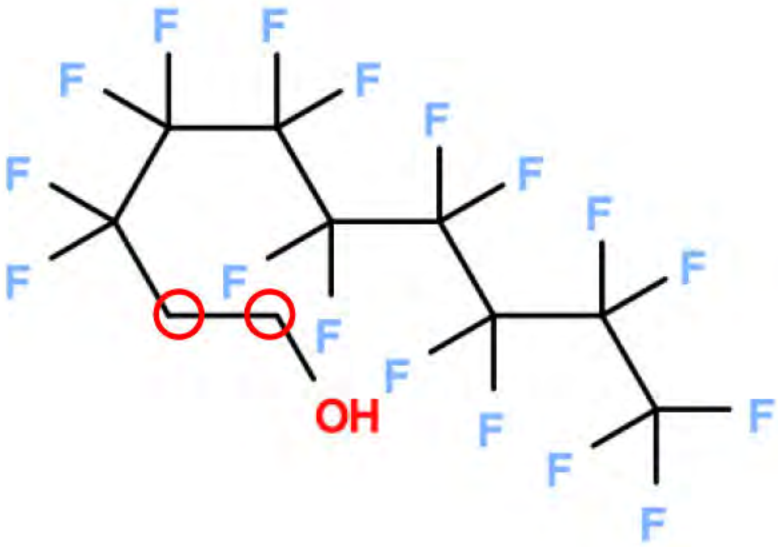
Perfluorinated:

All C-H bonds replaced with C-F bonds



Polyfluorinated:

Some C-H bonds replaced with C-F bonds



Chain lengths

The name of a chemical will tell you how long the carbon backbone is.

e.g. perfluoro**oct**ane sulfonate (PF**O**S)

= 8 carbons

Number of carbons		
1	meth-	Me
2	eth-	Et
3	prop-	P
4	but-	B
5	pent-	Pe
6	hex-	Hx
7	hept-	Hp
8	oct-	O
9	nona-	N
10	deca-	D
11	undeca-	UnD
12	dodeca-	DoD

Head groups

The name of a chemical will also tell you what the head group is. This helps determines the type of PFAS.

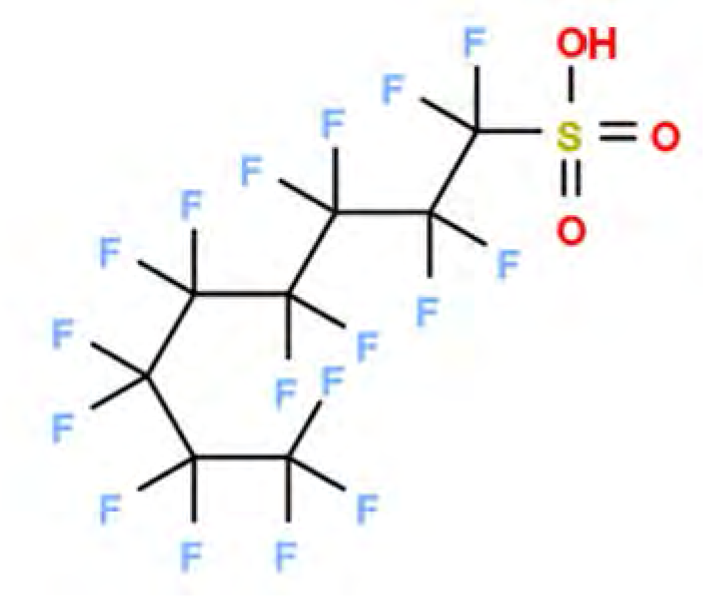
e.g. perfluorooctane <u>sulfonate</u> (PFO**<u>S</u>**)

= sulfonate

Some types of PFAS head groups	
Sulfonates	e.g. PFOS
Carboxylates	e.g. PFOA
Phosphonates	e.g. PFOP

Sulfonates

- 3M chemistry (1950 +)
- Includes PFOS, PFHxS
- Used in fire foam, chrome plating
- Moderately soluble with limited volatility
- No degradation
- PFBS now used



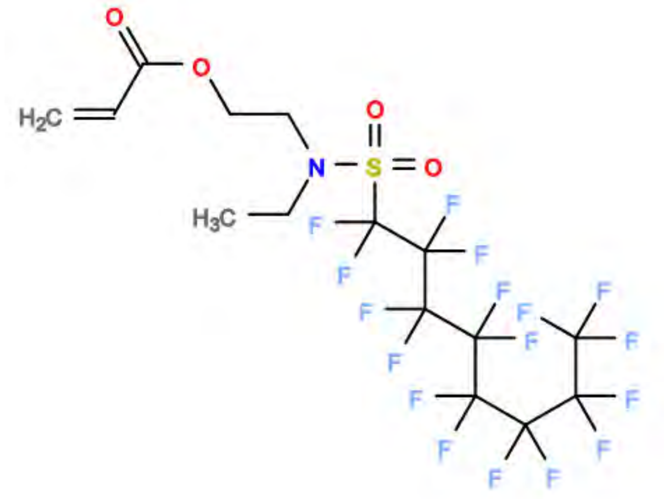
Perfluorooctane sulfonate
(PFOS)

Stockholm Convention

- PFOS was identified as a Persistent Organic Pollutant (POP) under the Stockholm Convention in 2009.
- POPs are:
  - toxic
  - bioaccumulative
  - persistent
  - Undergo long range transport

Sulfonamides

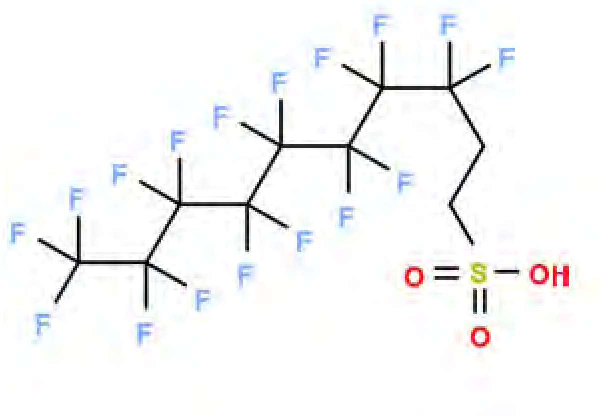
- Small chemicals and polymers
- Small chemicals used in fire foam, polymer manufacture
- Polymers used in paints, textile and paper treatments
- Some volatile
- Degradation to sulfonates



N-ethylperfluorooctane sulfonamidoethyl acetate (EtFOSAC)

Fluorotelomer sulfonates

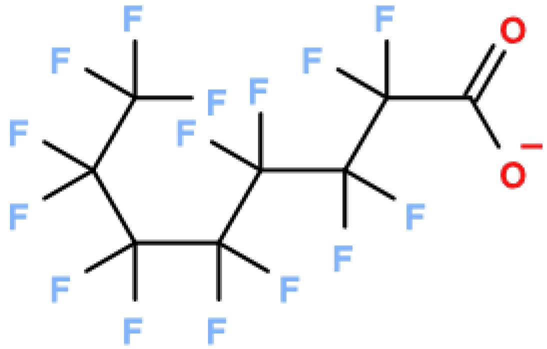
- No industrial use
- Present in environment as intermediate degradation product
- Limited data on properties
- Minor degradation to carboxylates



8:2 fluorotelomer sulfonate
(8:2 FTS)

Carboxylates

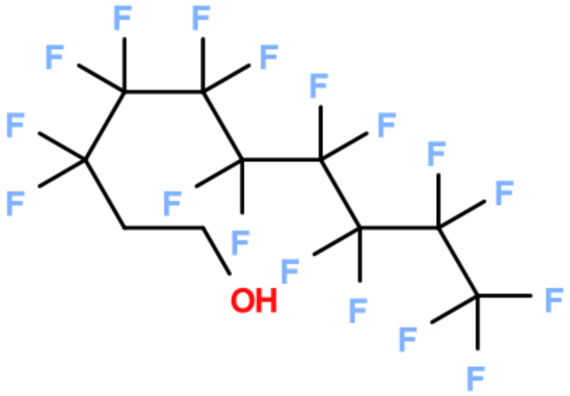
- DuPont chemistry (1940 +)
- Includes PFOA
- Used to make Teflon
- Volatile and highly soluble
- Presence primarily due to degradation of fluorotelomer alcohols
- No degradation
- PFHxA now used



Perfluorooctanoic acid
(PFOA)

Fluorotelomer alcohols

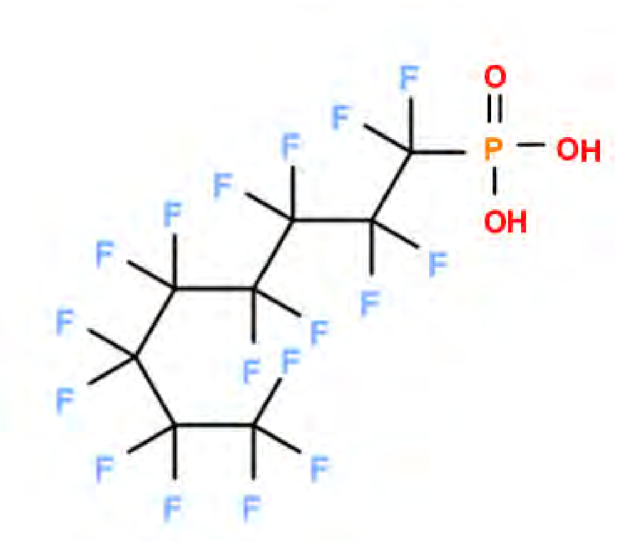
- Includes 8:2 FTOH
- Used to make polymers, which are used in paints and textile treatments
- Volatile and highly soluble
- Environment presence primarily due to degradation of polymers
- Degradation to carboxylates



8:2 fluorotelomer alcohol
(8:2 FTOH)

Phosphonates

- DuPont chemistry (1960 +)
- Used in household cleaning products, paper treatments
- Very limited information on properties



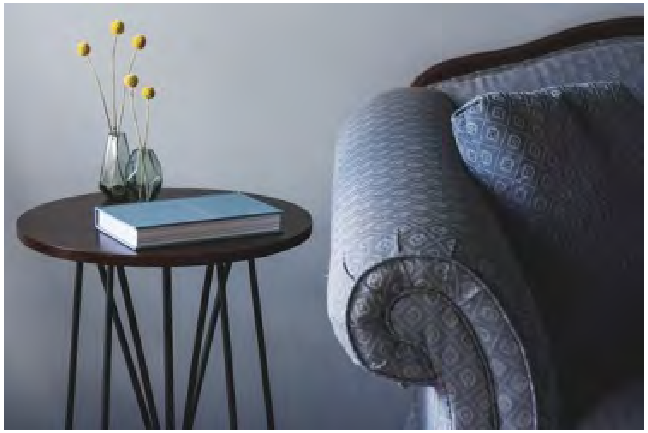
Perfluorooctane phosphonate
(PFOP)

Environmental concentrations

- In Australian drinking water:
  - PFOS: up to 0.02 µg/L
  - PFOA: up to 0.01 µg/L
- PFOA, PFHxS and PFHxA detected in 100% of samples from Parramatta River and Brisbane River

Environmental concentrations

- In the US, at least 6 PFAS identified in more than 70% of household dust samples.
- Average Australian blood concentration:
  - PFOS: 15.2 ng/L
  - PFOA: 6.4 ng/L
  - PFHxS: 3.1 ng/L
  - PFNA: 0.8 ng/L



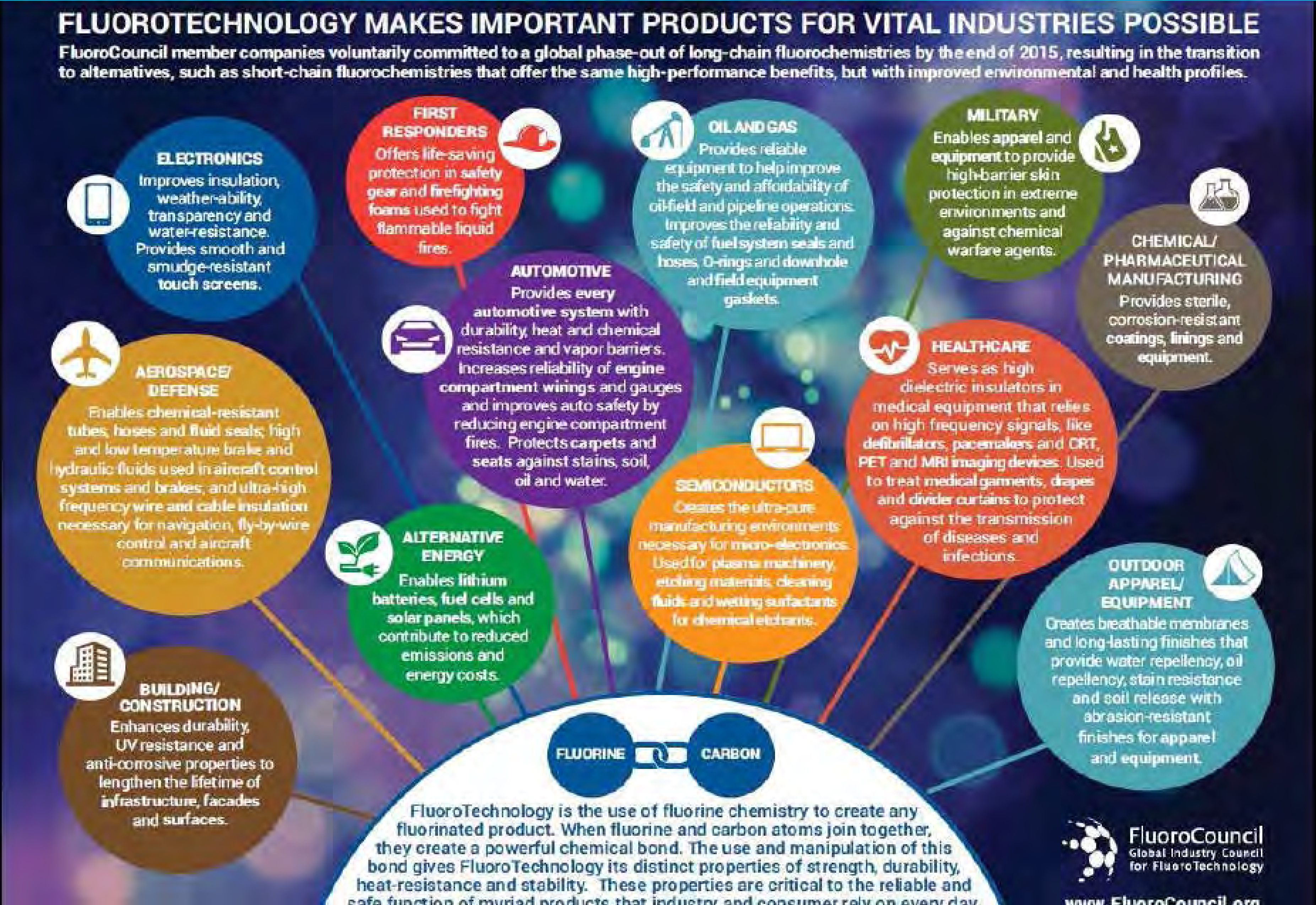
Bioaccumulation

- Peak bioaccumulation occurs around C6-8
- Novel bioaccumulation mechanism, difficult to predict
- PFOS undergoes high bioconcentration and biomagnification
- PFOA undergoes limited bioconcentration in fish but high biomagnification in marine mammals

Environmental toxicity

- Non-standard intergenerational fish studies show:
  - ⍰Chronic Effect to PFOS – Lowest Observed Effect Concentration in Zebra Fish of 0.7 µg/L (see attached Water Quality Guideline for PFOS)
- Some evidence that PFOA inhibits vitellogenin, estrogen and thyroid hormones

Background Levels
Where Do We Find PFASs?



FLUOROTECHNOLOGY MAKES IMPORTANT PRODUCTS FOR VITAL INDUSTRIES POSSIBLE

FluoroCouncil member companies voluntarily committed to a global phase-out of long-chain fluorochemistries by the end of 2015, resulting in the transition to alternatives, such as short-chain fluorochemistries that offer the same high-performance benefits, but with improved environmental and health profiles.

ELECTRONICS
Improves insulation, weather-ability, transparency and water-resistance. Provides smooth and smudge-resistant **touch screens.**

FIRST RESPONDERS
Offers life-saving protection in **safety gear and firefighting foams** used to fight flammable liquid fires.

OIL AND GAS
Provides reliable equipment to help improve the safety and affordability of oil-field and pipeline operations. Improves the reliability and safety of **fuel system seals and hoses, O-rings and downhole and field equipment gaskets.**

MILITARY
Enables **apparel and equipment** to provide high-barrier skin protection in extreme environments and against chemical warfare agents.

CHEMICAL/ PHARMACEUTICAL MANUFACTURING
Provides sterile, corrosion-resistant **coatings, linings and equipment.**

AUTOMOTIVE
Provides **every automotive system** with durability, heat and chemical resistance and vapor barriers. Increases reliability of **engine compartment wirings and gauges** and improves auto safety by reducing engine compartment fires. Protects **carpets and seats** against stains, soil, oil and water.

AEROSPACE/ DEFENSE
Enables chemical-resistant **tubes, hoses and fluid seals;** high and low temperature brake and **hydraulic fluids used in aircraft control systems and brakes;** and ultra-high **frequency wire and cable insulation** necessary for navigation, fly-by-wire control and aircraft communications.

HEALTHCARE
Serves as high dielectric insulators in medical equipment that relies on high frequency signals, like **defibrillators, pacemakers and CRT, PET and MRI imaging devices.** Used to treat **medical garments, drapes and divider curtains** to protect against the transmission of diseases and infections.

SEMICONDUCTORS
Creates the ultra-pure manufacturing environments necessary for **micro-electronics.** Used for **plasma machinery, etching materials, cleaning fluids and wetting surfactants for chemical etchants.**

ALTERNATIVE ENERGY
Enables **lithium batteries, fuel cells and solar panels,** which contribute to reduced emissions and energy costs.

OUTDOOR APPAREL/ EQUIPMENT
Creates breathable membranes and long-lasting finishes that provide water repellency, oil repellency, stain resistance and soil release with abrasion-resistant **finishes for apparel and equipment.**

BUILDING/ CONSTRUCTION
Enhances durability, UV resistance and anti-corrosive properties to lengthen the lifetime of **infrastructure, facades and surfaces.**

FLUORINE **CARBON**

FluoroTechnology is the use of fluorine chemistry to create any fluorinated product. When fluorine and carbon atoms join together, they create a powerful chemical bond. The use and manipulation of this bond gives FluoroTechnology its distinct properties of strength, durability, heat-resistance and stability. These properties are critical to the reliable and safe function of myriad products that industry and consumer rely on every day.

FluoroCouncil
Global Industry Council for FluoroTechnology
www.FluoroCouncil.org

Human health impacts

Human studies

- Blood levels in PFAS factory workers 100 – 1 000 times higher than the general population
- Long half life (3.8 years for PFOA, 5.4 years for PFOS)
- Associations found between:
  - PFOS exposure and increased cholesterol and triglycerides, and changes in thyroid hormones
  - PFOA exposure in pregnant women and reduced birth weight
- No proven causal relationship between PFAS exposure and adverse human health effects

Human health impacts

Animal studies (PFOS and PFOA)

- Mainly stored in the liver, lungs, kidneys and blood and eliminated in urine
- Do not damage DNA but may cause cancer with prolonged exposure to high levels
- PFOS increases oestradiol, changes thyroid hormone levels, and increases noradrenaline in the brain. PFOA inhibits testosterone levels.

Human health impacts

Animal studies cont.

- Limited data show PFOS and PFOA have:
  - Adverse impacts on immune system responsiveness
  - Reproductive and developmental toxicity
- PFOS also interferes with the metabolism of fatty acids, lipids and lipoproteins

Document 16

Per- and poly fluoroalkyl substances - overview

What is the PFAS problem?

- Per- and poly-fluoroalkyl substances (PFAS) are a group of manufactured chemicals (numbering over 3,000 chemicals) that have been widely used globally, since the 1950s. The substances most commonly referred to are PFOS[1], PFOA[2] and PFHxS[3].
- PFAS have become a focus of concern: they persist in the environment (no known natural process breaks them down); they easily migrate many kilometres from source; and they bio-accumulate.
- PFAS have been used in the manufacture of household and industrial products because they resist heat, stains, grease and water. Examples of PFAS uses (past and present) include: consumer products (carpets, leather, upholstery, apparel, cosmetics, sunscreens, paper, packaging, rubber, plastics, electronic parts for printers and copiers), insecticides, metal plating, plastics etching, fire-fighting foam, photographic materials, aviation hydraulic fluid and medical devices.

Fire Fighting Foams

- Both the public and private sectors worldwide have used PFAS fire-fighting foams for over 30 years. Although this accounts for less than 5% of PFAS used in Australia, it is a significant source of dispersal of contamination, in the vicinity of fire training grounds (particularly Defence bases, airports and Rural Fire Service grounds).
- Because PFAS have been used so extensively, many sites (airports, firefighting training, petrochemical facilities, industrial areas and landfills) are likely to be contaminated.

Health Concerns and government advice

- While we know that PFAS can persist in humans, animals and the environment for a long time, we cannot conclusively say that PFAS exposure is harmful to human health. Unlike in most animals, the human body gets rid of PFAS slowly, with a half-life measured in years.
- Most Australians have measurable levels of PFAS in their blood, although background levels have been declining. People working in or living near contaminated sites may have higher levels than the general public.
- Direct ingestion of contaminated drinking water (usually bore water) is the pathway of greatest concern.
- Australian governments are issuing precautionary advice to minimise exposure, while research is ongoing to determine whether there are human health impacts of exposure.
- To support risk assessments undertaken as part of PFAS site investigations, the Commonwealth Department of Health commissioned a report by Food Standards Australia New Zealand (FSANZ) entitled *Perfluorinated Chemicals in Food*, published in April 2017. FSANZ determined maximum acceptable amounts of the three main PFASs of concern that an individual could consume on a daily basis for an entire lifetime, without risk to health. These are expressed as Total Daily Intakes (TDIs).
- In this report, FSANZ recommended that there is no need for specific regulations, testing, and maximum PFAS levels for the general food supply.

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[1] PFOS = Perfluorooctane sulfonate, also known as perfluorooctane sulfonic acid.

[2] PFOA = Perfluorooctanoic acid.

[3] PFHxS = Perfluorohexane sulfonate, also known as perfluorohexane sulfonic acid.

- In order to exceed the TDIs FSANZ recommended for these chemicals, a person would have to consume all their food, all the time, from a contaminated site.
- As there are no regulated Maximum Levels for any PFAS in any foods in Australia or overseas, there are currently no restrictions on domestic or international trade in agricultural or aquacultural products.

Scope of the problem

- The Commonwealth has identified 139 potential Commonwealth managed sites with PFAS use or stockpiles and there are many hundreds (if not thousands) of state owned and private sites of concern.
- Of greatest concern for the Commonwealth are those sites like Williamtown, NSW and Oakey, Qld that have a high incidence of PFAS dispersal with an underground aquifer used for drinking water and irrigation of crops and livestock. However, if people have access to uncontaminated reticulated water (e.g. near metropolitan and large regional airports) the exposure pathways for humans is greatly reduced.

Government responses

- The Australian Government has established a PFAS Taskforce which has improved Commonwealth cooperation and collaboration with states and territories.
- Internationally, most of the action in response to PFAS is centred on investigations and the provision of alternative supplies of water (US and Sweden)– there has been no movement by other governments to buy back land or provide significant compensation, although in the US there has been some successful litigation, notably:
    - A 3,000 plus member class action against Dupont settled for USD$607 million.
    - Some individual payouts against manufacturers linked to cancer of several million dollars.
- The Australian Government is responding to PFAS contamination in a range of ways including: investigating contaminated sites, developing an intergovernmental agreement with states and territories, considering new policies, supporting further research, liaising with industry bodies, and responding to two class actions before the Federal Court.

Communication and Community Expectations

- The focus of media attention over the last two years has been on Oakey and Williamtown. More recently, media attention has focused on Katherine, NT. With a few exceptions, most of the attention has been limited to local media.
- There is generally a poor understanding in the community about the risks associated with exposure to PFAS and sensational reporting by media – especially the Newcastle Herald and some talk show hosts including Alan Jones and John Laws. ABC's Four Corners program on PFAS contamination (9 October 2017) brought the issue to a level of national awareness.
- There have been ongoing concerns in the community about peoples' health and the values of their properties associated with fear of the contamination plumes around Oakey and Williamtown.
- There has been a steadily growing expectation about land buy backs that has been mentioned as under consideration by Government, among other options, by the Prime Minister, the Minister for Defence and the Assistant Minister to the Prime Minister.

AUSTRALIAN AND NEW ZEALAND GUIDELINES FOR FRESH AND MARINE WATER QUALITY

GUIDELINES FOR THE PROTECTION OF AQUATIC ECOSYSTEMS

DEFAULT GUIDELINE VALUES FOR TOXICANTS

PERFLUOROOCTANOIC ACID (PFOA) – FRESH

JUNE 2017

SUMMARY

Perfluorooctanoic acid (PFOA) is a breakdown product of a family of precursor chemicals (referred to as perfluoroalkyl and polyfluoroalkyl substances, PFASs) containing the perfluoroalkly moiety. Uses of PFOA include: stain and water resistant coatings; non-stick coatings in cookware; fire-fighting foams, and food packaging (e.g., microwave popcorn bags) (Seow, 2013; Zhang et al., 2013; Environment Canada, 2012).

Due to the fluorine substitution for hydrogen on the carbon chain, PFASs are chemically very stable. PFOA itself has properties of being highly water soluble and will predominantly dissociate under typical environmental conditions into the perfluorooctanoate anion. PFOA will also adsorb moderately to soils/sediments, and is resistant to photolysis and hydrolysis, biodegradation and metabolism (Wei et al., 2007; Oakes et al., 2004; Zhang et al., 2013). Bioconcentration factors (BCF) for PFOA in fish range from less than 2 to 27 (Hekster et al., 2002; Environment Canada, 2012) although for PFASs, BCFs tend not to be reliable indicators of potential for PFOA to bioaccumulate or biomagnify. PFASs such as PFOA have greater potential to biomagnify in mammalian top predators compared to aquatic animals such as fish because of slower rates of elimination via respiration. In Australia, PFOA is a categorised as a persistent, bioaccumulative, and toxic (PBT) substance (NICNAS, 2015).

PFOA has a carboxylic acid group at the end of the fluorinated carbon chain. The position and number of fluorine atoms determine the characteristics of the PFAS. There are a number of precursors and derivatives with fewer fluorine atoms that are present in association with PFOA and are routinely reported in analysis of environmental waters. Select derivatives of PFOA (salts such as the sodium and ammonium salt (ammonium perfluorooctanote, APFO)) have been considered in preparation of this Default Guideline Value (DGV), whereas other fluorinated precursors (including those termed “telomers”) that may transform to PFOA, have not been considered in preparation of this DGV.

The DGVs are expressed as total PFOA. The ecotoxicological tests used to generate the DGVs have been conducted on either analytical or commercial grade PFOA. It is assumed that these include both linear and branched isomers of PFOA (i.e., the DGVs are assumed to represent total PFOA). Most PFOA that was produced for manufacturing was based on the electrochemical fluorination (ECF) process that resulted in a mixture of linear (70-80%) and branched (20-30%) isomers (Buck et al, 2011).

It is considered possible that the available chronic aquatic toxicology data used to derive the DGV do not adequately characterise the adverse effects at low concentrations of PFOA, or possible reproductive, endocrine, or multigenerational effects. Review of the DGV for the closely related chemical species PFOS suggests toxicity at lower concentrations than reported in studies available at time of preparation of this DGV for PFOA. Furthermore, given the evidence for PFOA to bioaccumulate and biomagnify in wildlife (notably in fish-eating upper trophic level predators), the 99% species protection level is recommended for adoption in assessment of slightly to moderately disturbed ecosystems.

The DGVs for PFOA are defined as having "moderate" reliability according to the Revised Method for Deriving Australian and New Zealand Water Quality Guideline Values for Toxicants. However, there is uncertainty as to whether the currently available aquatic toxicology data adequately characterise the adverse effects at low concentrations of PFOA, or possible reproductive, endocrine, or multigenerational effects.

The DGVs for a range of protection levels are:

Default guideline value type	**PFOA (freshwater) toxicity default guideline value (µg/L)**
Reliability	*Moderate*
High conservation value systems (99% species protection)	19
Slightly to moderately disturbed systems (95% species protection)	220
Highly disturbed systems (90% species protection) (80% species protection)	632 1,824

1 INTRODUCTION

Perfluorooctanoic acid (PFOA) is a perfluoroalkyl substance (PFAS) that has been in production and use since the late 1940s (Giesy, 2010). NICNAS (2015) defines PFOA as "*perfluorooctanoic acid and its conjugate base anion (i.e. the perfluorooctanoate anion)*". The derivatives and precursors of PFASs that degrade to PFOA are the main source of PFOA in the environment. Uses of PFASs which degrade to PFOA are wide-ranging and include: food packaging; cleaning products; pesticides; stain and water resistant coatings used in and on fabrics, leather and paper; non-stick coatings in cookware; and fire-fighting foams (Seow, 2013; Zhang et al., 2013; Giesy, 2010; Wei et al., 2007; Oakes et al., 2004). PFASs have unique surface active properties making them effective surfactants. PFASs repel both oil (lipophobic) and water (hydrophobic) (Environment Canada, 2012).

PFOA has a carboxylic acid group at the end of the fluorinated carbon chain. The carboxylate end of PFOA is hydrophilic and the fluorocarbon tail is both hydrophobic and lipophobic. Due to the fluorine substitution for hydrogen on the carbon chain, PFASs are chemically very stable. PFOA is also resistant to photolysis and hydrolysis (greater than 92 years according to Hekster et al., 2002), and biodegradation and metabolism (Wei et al., 2007; Oakes et al., 2004; Zhang et al., 2013). The distribution pattern of PFOA in animals can vary across taxa, but generally partitions to the liver and plasma (Ng and Hungerbühler 2014; Oakes et al., 2004). A half-life of 9 days in rats and 4.37 years in occupationally exposed humans has been reported for PFOA (Oakes et al., 2004).

PFOA is also highly water soluble, with a reported water solubility of 3,727 mg/L (NICNAS, 2015). Water solubility for surface-active substances is determined from the critical micelle concentration (NICNAS, 2015), PFOA will completely dissociate in water and will adsorb moderately to soils/sediments (a Log K_{oc} of 2.06 reported in ESFA (2008) noting however that, due to the surface-active properties of PFASs, the reliability of partitioning estimates depend on the method used). The octanol-water partition coefficient (K_{ow}) for PFOA is not a reliable indicator of potential to bioaccumulate. This is a consequence of possessing (very unusually) both lipophobic and hydrophobic properties. Bioconcentration factors (BCF) in fish have been experimentally determined for PFOA and range from less than 2 (Hekster et al., 2002) to 27 (Environment Canada, 2012) although BCFs for PFASs are not a reliable indicator of potential to biaccumulate in biota based on evidence of biomagnification noted in top predators, in particular predators consuming PFOA-containing aquatic organisms (Kelly et al., 2009).

The extensive use of PFOA (and other PFASs that are precursor of PFOA), high solubility, and slow degradation rates of PFOA have resulted in the long-range transport and global distribution (including detection in Arctic regions) and ubiquitous presence in biotic and abiotic media. PFOA may be also result from degradation of precursors such as fluorotelomer alcohols. PFOA exists as the following forms: acid, acid fluoride, and salts of potassium, sodium, silver, and ammonium. The ammonium salt (ammonium perfluorooctanoate, APFO) is most widely used. Concentrations of PFOA in the environment are generally present in lower concentrations than PFOS (ESFA, 2008). Reported concentrations of PFOA in biota tissues and abiotic media (environmental waters) range from nano-gram per litre/kilogram concentrations to microgram per litre/kilogram (ESFA, 2008; Wei et al., 2007).

There is experimental evidence that PFOA bioaccumulates, and biomagnifies in food chains. PFASs are understood to bind to proteins (Spachmo and Arukwe, 2012) and are readily absorbed from the diet as evidenced in dietary exposure studies in fish and rats (Kelly et al., 2009). The potential for PFAS such as PFOA to bioaccumulate and biomagnify is determined primarily by the rates of elimination. Elimination rates for PFASs were reported to be higher in fish (via gills to ambient water) compared to air breathing animals (birds and mammals). This is because elimination via respiratory routes is slow and assumed to be a consequence of the low volatility and low rates of protein to air elimination for PFASs (Kelly et al., 2009). Hence PFASs such as PFOA have greater potential to biomagnify in air breathing animals compared to aquatic animals such as fish.

Different regulatory jurisdictions have differing criteria for classifying or categorising a chemical as persistent, bioaccumulative and toxic (PBT). PFOA is classified as PBT in Europe and in Australia, PFOA has been categorised as a PBT substance according to domestic categorisation criteria (NICNAS, 2015).

Reproductive and endocrine effects have been reported for PFOA. The research and evidence of reproductive and endocrine effects from PFASs, most notably perfluorooctane sulfonate (PFOS) but including PFOA, is well documented in human (mammalian) toxicology. There is growing evidence in the aquatic toxicology literature that PFOA is a reproductive toxicant that can result in endocrine and multigenerational effects in aquatic wildlife (Spachmo and Arukwe, 2012; Ji et al., 2008; Wei et al., 2007; Oakes et al., 2004). This is discussed in section 2.

2 AQUATIC TOXICOLOGY

A literature review of the effects of PFOA on freshwater organisms indicated that, compared to PFOS, there was a less extensive acute and chronic toxicity dataset. The majority of aquatic toxicology studies have been performed using the peflouroocanoic acid (C8, PFOA with the molecular formula $C_7F_{15}COOH$, Chemical Abstracts Service Registry Number (CAS RN) 335-67-1). Fewer studies have been conducted with the ammonium salt (APFO, $C_8H_4F_{15}NO_2$, CAS RN 3825-26-1) and sodium salt (CAS RN 335-95-5). The molecular weights of the acid, ammonium and sodium salts are similar; at 414 g/mol, 431 g/mol, and 436 g/mol, respectively. The majority of chronic aquatic toxicity literature reviewed at the time of preparation of this DGV reported effect concentrations for the chemical salt of PFOA, rather than the PFOA anion, with only one study (Hanson et al (2005) reporting chronic effects in the aquatic plant *Myriphyllum* sp for the PFOA anion.

The effect concentrations used to derive the DGV have not been converted to the PFOA anion but reported as the form of PFOA tested. It has been assumed that the toxicity measured is due to the PFOA anion, rather than the cation present. In other words, toxic effects associated from the cation have been assumed to be insignificant.

Based on the data considered, there was no evidence that one taxonomic group was more sensitive to PFOA than any other. Three fish species are included in the DGV and represent individual studies rather than geomeans. The effects concentrations for fish span two orders of magnitude: a 56-d NOEC (growth of juveniles following exposure to the egg life stage) of 100 µg/L was reported in salmon, *Salmo salar* (Spachmo and Arukwe 2012); and NOECs (egg hatchability) of 10,000 µg/L for medaka (*Oryzias latipes*, Ji et al., 2008) and NOEC (mortality) of 40,000 µg/L rainbow trout (*Oncorhynchus mykiss*, Colombo et al., 2008).

Effects on macroinvertebrates similarly spanned a wide range of concentrations. The rotifer, *Brachionus calyciflorus*, reported a 28-d NOEC (survival) of 250 µg/L (Zhang et al., 2013). Reported effects for water fleas (*Daphnia magna*) were higher than the rotifer, with 21-d NOECs for reproduction of 10,000 µg/L and 12,500 µg/L (Li et al., 2010 and Ji et al., 2008, respectively). The *D. magna* data were used to calculate a geomean of 11,180 µg/L. A 7-d NOEC (reproduction) of 3,125 µg/L was reported for the water flea, *Moina macrocopa* (Ji et al., 2008). NOECs (mortality and growth) for chironomids (*Chironomus tentans*) following a 10-d exposure were both 100,000 µg/L (MacDonald et al., 2004).

Two plant studies were used in the species sensitivity distribution (SSD) for the DGV. EC10s for growth were reported for two species of *Myriphyllum*. *Myriphyllum spicatum* reported a 21-d EC10 (growth) of 5,700 µg/L and *Myriophyllum sibricum* reported a 21-d EC10 (dry weight) of 7,900 µg/L (Hanson et al., 2005). Three microalgae studies were included in the SSD. Variation in effects concentrations on growth were noted between the microalgae species. *Pseudokirchneriella subcapitata* (Colombo et al., 2008) reported a 4-d NOEC of 12,500 µg/L, *Scenedesmus obliquus* reported a 4-d EC50 of 8,800 µg/L (Hu et al., 2004), and the cyano-bacterium, *Anabaena CPB4337*, reported a 3-d EC50 of 72,300 µg/L (Rosal et al., 2010).

Numerous acute mortality studies on PFOA were available. These studies included laboratory tests undertaken on rotifers, flatworms, shrimps, snails and fish with effects concentrations ranging from 125,000 µg/L in the waterflea, *Daphnia magna* (Li, 2009), to 707,000 µg/L in the Rainbow trout (Colombo et al., 2008). Acute endpoints, other than mortality, included valve closure and foot movement in two bivalves, *Lampsilis siliquoida* (2-d EC50 164,400 µg/L valve closure; 4-d EC50 500,000 µg/L foot movement) and *Ligumia recta* (2-d EC50 161,300 µg/L valve closure; 4-d EC50 foot movement 500,000 µg/L) (Hazelton et al., 2012). Other acute endpoints include developmental effects in the Zebrafish (*Danio rerio*) (5-d NOEC 5,000 µg/L) (Hagenaars et al., 2011), immobility in the waterflea (*Moina macrocopa*) (2-d NOEC 62,500 µg/L) (Ji et al., 2008) and growth (photosynthesis) in the microalgae (*Pseduokirchneriella subcapitata*) (4.5h NOEC 748,300 µg/L) (Ding et al., 2012).

The majority of available aquatic toxicity studies for PFOA represent acute exposures. Standard acute ecotoxicological studies do not target reproductive effects in macroalgae, macrophytes, invertebrates and fish because of the short duration of the test (insignificant in terms of the overall organism life-cycle) but also because acute exposures often entail lethal or sub-lethal endpoints. In addition, standard chronic aquatic toxicity studies can also fail to measure key reproductive effects such as endocrine effects. This is relevant when establishing protection levels for wildlife for a toxicant such as PFOA, as there is evidence in the human (mammalian) toxicology literature of reproductive effects from exposure to PFOA, and growing evidence of endocrine and multigenerational effects in the aquatic toxicology literature. At present, there appear to be very few multigenerational studies or endocrine effects assessments of PFOA on aquatic organisms. The following paragraphs summarise the studies which indicate reproductive, endocrine or multigenerational effects due to PFOA exposure. These studies did not meet the quality acceptance criteria or satisfy the methodology used in this DVG derivation and so were excluded from the SSD. However, given that PFASs (including PFOA) are considered reproductive toxicants, the following studies are pertinent to consider in applying the DGV.

Lu and Chen (2012) report abnormalities in the sperm of a frog (*Rana nigromaculata*) exposed to 1 µg/L PFOA for 20 days. The deformities are not described and furthermore, effects on unfertilised gametes are not considered to be ecological relevant. However, this study provides evidence of possible endocrine effects at very low exposures.

Oakes et al., (2004) and Wei et al., (2007) measured changes to reproductive hormones, testes and ovaries in the fathead minnow *Pimephales promelas* and the rare minnow *Gobiocypris rarus*, respectively following exposure to PFOA. Oakes et al 2004 exposed fathead minnow to concentrations of 300 µg/L, 1,000 µg/L, 30,000 µg/L, and 100,000 µg/L of PFOA in microcosms for 39 days and reported significant reductions in circulating plasma steroid levels as well as a slight increase in time to first oviposition and a decrease in overall egg production. Wei et al. (2007) noted the development of oocytes in the testes of male fish and degeneration of female ovaries in adult rare minnows exposed to concentrations of 3,000 µg/L, 10,000 µg/L and 30,000 µg/L PFOA for up to 28 days. The number of sperm and various stages of germ cells within the spermatogenic cycle in the 10,000 µg/L and 30,000 µg/L PFOA treatments were lower than those in control males.

Given that PFASs are considered reproductive toxicants, and effects have been reported at very low concentrations, only data from chronic studies using PFOA were used to derive the SSD. It was considered that inclusion of converted acute studies would result in a DGV that could be under-protective. As further studies into the reproductive effects of the PFASs are reported in the literature, it is possible that multigenerational or acceptable reproductive endpoints will demonstrate effects at concentrations lower than reported herein.

3 FACTORS AFFECTING TOXICITY

To date, there is no evidence to suggest there are factors affecting the toxicity of PFOA to freshwater aquatic organisms.

4 GUIDELINE DERIVATION

The DGVs for PFOA in freshwater are provided in Table 1.

The numerical protection levels for PFOA in freshwater aquatic ecosystems have been derived according to the procedures outlined in the Revised Method for Deriving Australian and New Zealand Water Quality Guideline Values for Toxicants. These methods are not intended to specify species protection concentrations for air-breathing animals that live in aquatic ecosystems, or that prey on aquatic organisms. The DGVs derived for protection of aquatic ecosystems may not account for effects which result from the biomagnification of toxicants such as PFOA in air breathing animals.

The DGVs for PFOA are defined as of "moderate" reliability according to the Revised Method for Deriving Australian and New Zealand Water Quality Guideline Values for Toxicants. However, there is uncertainty as to whether the currently available aquatic toxicology data adequately characterise the adverse effects at low concentrations of PFOA, or possible reproductive, endocrine, or multigenerational effects..

Table 1 Default guideline values (µg/L) for PFOA for the protection of freshwater ecosystems.

PFOA default guideline values; freshwater[a]	
Percent species protection	**Concentration *(µg/L)***
99%	19
95%	220
90%	632
80%	1,824

Reliability classification[b]	
Criterion	**Result**
Sample size	12
Type of toxicity data	Chronic
SSD model fit	Poor
Reliability	Moderate

[a] Guideline values were derived using the Burrlioz 2.0® software.

[b] See Warne et al (2014) for definitions of guideline value "reliability".

TOXICITY DATA USED IN DERIVATION

A summary of the toxicity data and conversions used to derive the DGVs are provided in Table 2. Further details about the data and test conditions are given in Attachment A.

Twelve chronic data from six taxonomic groups (algae, rotifers, crustaceans, insects, plants and fish) were available. Of these 12 chronic endpoints, two were EC10 endpoints, and eight were NOECs. EC10 and NOECs are preferred endpoints that require no conversion. Two chronic EC50 endpoints were converted to a NOEC equivalent by dividing by the default factor of 5. In all, 12 chronic NOECs or NOEC-equivalents were used to derive the DGV.

SPECIES SENSITIVITY DISTRIBUTION

The cumulative frequency (species sensitivity) distribution of the 12 chronic freshwater PFOA chronic toxicity data reported in Table 2 is shown in Figure 1.

Table 2 Summary of chronic toxicity data values used to derive the default guideline values for PFOA

Taxonomic group	Species	Life stage	Duration (h)	Type (acute/ chronic)	Toxicity measure [a]	Toxicity value (µg/L)	Estimated chronic NOEC (µg/L)
Microalgae	*Scenedesmus obliquus*	-	96	Chronic	EC50	44,000	8,800[b]
	Pseudokirchneriella subcapitata	-	96	Chronic	NOEC	12,500	12,500[c]
	Anabaena CPB4337	-	72	Chronic	EC50	72,300	14,460[b]
Rotifera	*Brachionus calyciflorus*	Neonates	672	Chronic	NOEC	250	250 [c]
Macrophyte	*Myriophyllum spicatum*	-	504	Chronic	EC10	5,700	5,700[c]
	Myriophyllum sibricum	-	504	Chronic	EC10	7,900	7,900[c]
Crustacean	*Moina macrocopa*	Neonates	168	Chronic	NOEC	3,125	3,125 [c,d]
	Daphnia magna	Neonates	504	Chronic	NOEC	11,180	11,180 [c,d]
Insecta – Diptera	*Chironomus tentans*	Larvae	240	Chronic	NOEC	100,000	100,000 [c]
Fish	*Salmo salar*	Eggs	1344	Chronic	NOEC	100	100 [c]
	Oryzias latipes	Eggs	336	Chronic	NOEC	10,000	10,000 [c]
	Oncorhynchus mykiss	Eggs	2040	Chronic	NOEC	40,000	40,000 [c]

[a] The measure of toxicity being estimated/determined: NOEC: No observed effect concentration; LOEC: Lowest observed effect concentration; LC_{50}: median lethal concentration; EC_{10}: 10% effects concentration; IC10: 10% inhibition concentration

[b] Converted from chronic EC_{50} (NOEC = EC_{50}/5)

[C] Actual NOEC

[c] No conversion from EC/IC_{10} to NOEC required

[d] Geomean

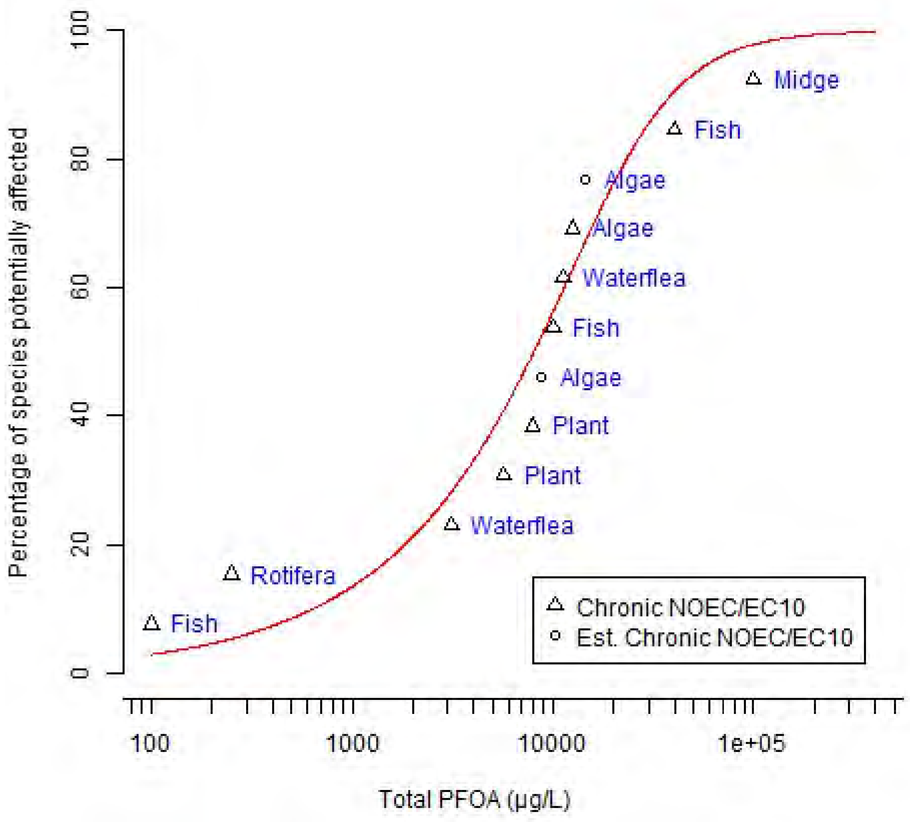

Figure 1 Cumulative frequency distribution (from Burrlioz 2.0©) for PFOA

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GLOSSARY, ACRONYMS AND ABBREVIATIONS

Acute toxicity	An adverse effect that occurs as the result of a short exposure period to a chemical relative to the organism's life span.
APFO	Ammonium perfluorooctanoate.
BAF (Bioaccumulation Factor)	Bioaccumulation is the process by which chemical substances are accumulated by aquatic organisms by all routes of exposures i.e., dietary and the ambient environment. Bioaccumulation is the net result of competing processes of chemical uptake into the organism at the respiratory surface and from the diet and chemical elimination from the organism including respiratory exchange, fecal egestion, metabolic biotransformation. The degree to which bioaccumulation occurs can be expressed as a bioaccumulation factor (BAF), at steady state. The BAF can be expressed on wet weight, dry weight, and lipid weight bases. Most commonly, the weight of the organism is presented on a wet weight basis and the units of the BAF are L/kg.
BCF (Bioconcentration Factor)	Describes the degree to which a chemical can be concentrated in the tissues of an organism in the aquatic environment via absorption through the respiratory and dermal surfaces i.e. dietary exposure is excluded. It is the net result of competing rates of chemical uptake at the respiratory surface (e.g., gills in fish) and chemical elimination. At apparent equilibrium, the BCF is the concentration of a chemical in one or more tissues of the aquatic organisms divided by the average exposure concentration in the test, expressed in units of L/kg.
BMF (Biomagnification Factor)	Biomagnification is a process in which the thermodynamic activity of the chemical in an organism exceeds that of its diet and is expressed by a biomagnification factor (BMF). The BMF is the ratio of contaminant concentration in in an organism to that in its diet at steady state. BMF can be expressed on a wet weight basis or dry weight basis, or as a fugacity ratio.
CAS RN	Chemical Abstracts Service Registry Number
Chronic toxicity	An adverse effect that occurs as the result of exposure to a chemical for a substantial portion of the organism's life span or an adverse sub-lethal effect on a sensitive early life stage.
Default guideline value (DGV)	A guideline value recommended for generic application in the absence of a more specific guideline value (e.g. site-

	specific), in the Australian and New Zealand Water Quality Guidelines.
EC$_{50}$ (median effective concentration)	The concentration of material in water that is estimated to be effective in producing some lethal or growth response in 50% of the test organisms. The EC$_{50}$ is usually expressed as a time-dependent value (e.g. 24-hour or 96-hour EC$_{50}$).
Endpoint	Measured attainment response, typically applied to ecotoxicity or management goals
Guideline value (GV)	A measurable quantity (e.g. concentration) or condition of an indicator for a specific environmental value below which (or above which, in the case of stressors such as pH, dissolved oxygen and many biodiversity responses) there is considered to be a low risk of unacceptable effects occurring to that environmental value. Guideline values for more than one indicator should be used simultaneously in a multiple lines of evidence approach.
LC$_{50}$	Median lethal concentration
LOEC (Lowest observed effect concentration)	The lowest concentration of a material used in a toxicity test that has a statistically significant adverse effect on the exposed population of test organisms as compared with the controls.
NOEC (No observed effect concentration)	The highest concentration of a toxicant at which no statistically significant effect is observable, compared to the controls; the statistical significance is measured at the 95% confidence level.
PBT	Persistent, Bioaccumulative, and Toxic
PFAS	Perfluoroalkyl and polyfluoroalkyl substances, containing the perfluoroalkyl moiety
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate
POPs (Persistent Organic Pollutants)	As defined under The Stockholm Convention, POPs are organic compounds that possess toxic properties, resist degradation, bioaccumulate and are transported, through air, water and migratory species, across international boundaries and deposited far from their place of release, where they accumulate in terrestrial and aquatic ecosystems.
Species	A group of organisms that resemble each other to a greater degree than members of other groups and that form a reproductively isolated group that will not produce viable offspring if bred with members of another group.
SSD	Species Sensitivity Distribution

Toxicity	The inherent potential or capacity of a material to cause adverse effects in a living organism.

ATTACHMENT A. *Full details of chronic toxicity data used to derive PFOA (fresh) guideline values*

Phyla/ Division	Species	Life stage	Exposure duration (h)	Test type	Toxicity measure ^{b} (Test Endpoint)	Test medium	Temp. (°C)	Salinity (‰)	pH	Conc. (µg/L)	Reference
Microalgae	*Scenedesmus obliquus*	-	96	Chronic	EC50	HB-4 medium	24-26°C	-	6.8	8,800^{b,c}	Hu et al. 2014
	Pseudokirchneriella subcapitata	-	96	Chronic	NOEC	Reconstituted water	21-25°C	-	-	12,500^{d,e}	Colombo et al. 2008
	Anabaena CPB4337	-	72	Chronic	EC50	-	28°C	-	-	14,460^{b,c}	Rosal et al. 2010
Macrophyte	*Myriophyllum spicatum*	-	504	Chronic	EC10	Irrigation pond - well water	17.9-18.3°C	-	8.3-8.7	5,700^{f,g}	Hanson et al. 2005
	Myriophyllum sibricum	-	504	Chronic	EC10	Irrigation pond - well water	17.9-18.3°C	-	8.3-8.7	7,900^{f,g}	Hanson et al. 2005
Rotifera	*Brachionus calyciflorus*	Neonates	672	Chronic	NOEC	EPA media	20°C	-	-	250^{c,e}	Zhang et al. 2013
Crustacean	*Moina macrocopa*	Neonates	168	Chronic	NOEC	Moderately Hard water	20-22°C	-	-	3,125^{c,e}	Ji et al. 2008
	Daphnia magna	Neonates	504	Chronic	NOEC	ASTM test medium	19-21°C	-	-	10,000^{d,e}	Li 2010
	Daphnia magna	Neonates	504	Chronic	NOEC	Moderately Hard water	20-22°C	-	-	12,500^{c,e}	Ji et al. 2008
Insecta – Diptera	*Chironomus tentans*	Larvae	240	Chronic	NOEC	ASTM hard water	23°C	-	-	100,000^{c,e}	MacDonald et al. 2004

Phyla/ Division	**Species**	**Life stage**	**Exposure duration (h)**	**Test type**	**Toxicity measure [b] (Test Endpoint)**	**Test medium**	**Temp. (°C)**	**Salinity (‰)**	**pH**	**Conc. (µg/L)**	**Reference**
Fish	*Salmo salar*	Eggs/ embryos	1,344	Chronic	NOEC	Carrier solvent – methanol	5-7°C	-	-	100[c,e]	Spachmo and Arukwe 2012
	Oryzias latipes	Eggs/ embryos	336	Chronic	NOEC	Dechlorinated tap water	24-26°C	-	-	10,000[c,e]	Ji et al. 2008
	Oncorhynchus mykiss	Eggs/ embryos	2,040	Chronic	NOEC	Dechlorinated tap water	11.1-14.4°C	-	6.0-8.5	40,000[d,e]	Colombo et al. 2008

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[a] The measure of toxicity being estimated/determined: NOEC: No observed effect concentration; LOEC: Lowest observed effect concentration; LC_{50}: median lethal concentration; EC_{10}: 10% effects concentration; IC10: 10% inhibition concentration

[b] Converted from chronic LC_{50} (NOEC = $LC_{50}/5$)

[c] Stated as the acid form of PFOA, or assumed to be the acid form of PFOA

[d] Ammonium perfluorooctanoate, APFO

[e] Actual NOEC

[f] No conversion from EC/IC_{10} to NOEC required

[g] Exposure to the sodium salt of PFOA, concentration reported as the PFOA anion

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AUSTRALIAN AND NEW ZEALAND GUIDELINES FOR FRESH AND MARINE WATER QUALITY

GUIDELINES FOR THE PROTECTION OF AQUATIC ECOSYSTEMS

DEFAULT GUIDELINE VALUES FOR TOXICANTS

PERFLUOROOCTANE SULFONATE (PFOS) – FRESH

OCTOBER 2017

SUMMARY

Perfluorooctane sulfonate (PFOS) is a breakdown product of a family of precursor chemicals (referred to as perfluoroalkyl and polyfluoroalkyl substances, PFASs) containing the perfluoroalkyl moiety [7]. PFOS has been classified, globally and in Australia, as a persistent, bioaccumulative and toxic (PBT) substance [25,25,33,24,34].

Fluorine (rather than hydrogen) atoms are strongly bonded to the carbon chain, resulting in PFOS being chemically very stable with long half-lives: hydrolysis half-life of ≥ 41 years; photolysis half-life of > 3.7 years[28], and very slow rates of anaerobic and aerobic biodegradation.

Unlike the majority of Persistent Organic Pollutants (POPs), PFOS is both hydro-, and lipophobic and binds to proteins, rather than concentrates in the lipid fraction[28]. PFOS is highly water soluble (reported solubilities of 370 mg/L in freshwater to 680 mg/L in pure water[10,24]). The PFOS anion ($C_8F_{17}SO_3^-$) is released from a family of PFASs precursors. Common precursors are the acid, potassium, lithium or ammonium salts, and polymers containing the PFOS anion. Due to its unique surface-active properties, PFOS has both lipid- and water-repellent characteristics, and is resistant to typical environmental degradation processes including hydrolysis, photolysis, biodegradation and metabolism[12,16,27,28].

PFOS bioconcentrates, bioaccumulates and biomagnifies in aquatic food chains. Consequently, the 99% species protection level is recommended for adoption in assessment of slightly to moderately disturbed ecosystems.

The Default Guideline Values (DGVs) are expressed as total PFOS. Ecotoxicological tests have been conducted on either analytical or commercial grade PFOS. It is assumed that these include both linear and branched isomers of PFOS. (i.e. the DGVs are assumed to represent total PFOS). Most PFOS that was produced for manufacturing was based on the electrochemical fluorination (ECF) process that resulted in a mixture of linear (60-70%) and branched (30-40%) isomers.

The DGVs for PFOS are defined as having “very high” reliability according to the Revised Method for Deriving Australian and New Zealand Water Quality Guideline Values for Toxicants. However, because the data span greater than four orders of magnitude there is greater uncertainty, and lower confidence in the 99% species protection level.

The DGVs for a range of protection levels are:

Default guideline value type	**PFOS (freshwater) toxicity default guideline value (μg/L)**
Reliability	*Very High*
High conservation value systems (99% species protection)	0.00023
Slightly to moderately disturbed systems (95% species protection)	0.13
Highly disturbed systems	
(90% species protection)	2.0
(80% species protection)	31

1 INTRODUCTION

Perfluorooctane sulfonate (PFOS) is a breakdown product of a family of precursor chemicals (referred to as perfluoroalkyl and polyfluoroalkyl substances, PFASs) containing the perfluoroalkyl moiety [1]. PFASs were used extensively in the 1970s and 1980s in the manufacture of clothing and other textiles, food wrapper coatings, paper and packaging, metal plating, coating additives, cleaning products, stain repellents, pesticides, semi-conductors, surfactants and firefighting foams[5,8]. In the 1990s evidence began to surface that PFOS was present in measurable concentrations in humans and environmental media (air, water, soil, food and wildlife). This raised international concern regarding the health and environmental hazards posed by PFOS. Consequently, in 2000, the largest producer of PFOS in the United States, the 3M Company, announced it would voluntarily phase-out production of PFOS[6,7,11]. The 3M phase-out was complete by 2002[5,7]. However, since 2002, other companies have since taken-up production of PFASs including PFOS and its precursors/derivatives.

PFOS has been classified as a persistent, bioaccumulative and toxic (PBT) substance[26,6]. PBT chemicals, such as PFOS, persist in the environment, bioaccumulate in food chains and are toxic, posing a risk to human health and the environment[10,16,18,21]. Of the PFASs, PFOS has been found to accumulate in aquatic food chains and wildlife, and is generally the dominant PFAS in sampled biota tissues, regardless of the species or trophic level[10,32]. In 2009, PFOS was added to Annex B[1] of the Stockholm Convention on Persistent Organic Pollutants (POPs). At time of preparation of this DGV, Australia was yet to ratify the amendment to the Stockholm Convention (for PFOS, its salts and perfluorooctanesulfonyl fluoride). Australia implemented regulatory controls for PFOS and its direct precursors including prohibiting introduction or export without approval[26].

PFASs have fluorine rather than hydrogen atoms bonded to the carbon chain. The precursors of PFOS (the acid, potassium, lithium or ammonium salts) readily dissociate to the PFOS anion ($C_8F_{17}SO_3$-) when released to water. Perfluorooctane sulfonic acid is a very strong acid in water. The strong fluorine bonds gives PFOS unique surface-active (low surface energy) properties and results in PFOS having both lipid- and water-repellent characteristics and being chemically and biologically stable and persistent in the environment. PFOS is resistant to typical environmental degradation processes including: hydrolysis, photolysis, biodegradation and metabolism[12,16,27,28]. The hydrolysis half-life of PFOS has been reported to be ≥41 years and the photolysis half-life >3.7 years[24,28]. Laboratory tests assessing the stability and persistence of PFOS have shown that the only means of degradation is through high temperature incineration[34].

PFOS can enter the environment from spills or other releases from factories, during the use and disposal of products containing PFOS, or as waste products found in sewage outflows and landfill leachate. Of importance to note is that PFOS can enter the environment not only as the parent compound but also as the final metabolites of many PFASs due to degradation or metabolism[34]. Because of this, it is likely that PFOS concentrations will continue to be present in the environment over the long term.

Once released into the environment, PFOS disperses via transport in surface water, adsorption to particles (in water, sediment or air), and food chain transfer[34]. Based on the chemical characteristics of PFOS (low Henry's Law coefficient, high water solubility) it is considered that the aquatic environment is the environmental compartment of greatest concern[20,29]. Evidence of long-range transport of PFASs is provided by concentrations measured in environmental media and non-human biota, including Arctic wildlife[34]. Concentrations of PFOS have been reported as high as 3,770 ng/g in polar bears, 95.6 ng/g in seals, between 5.7 and 39 ng/g in various fish species, 1.8 ng/g in zooplankton and up to 42,200 ng/g in Herring Gull eggs[28]. Review of the international literature on concentrations of PFOS in surface water indicate detectable concentrations of nano-grams per litre,

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[1] Annex B includes a range of control measures to restrict and, where feasible, eliminate the release of POPs[33].

with concentrations increasing to micro-grams per litre in areas that are sources of long-term PFOS-release[15,35]. Concentrations of PFOS in waste water from treatment plants have been reported up to 5 μg/L[34]. Concentrations of PFOS in sediment have been found up to 53 μg/kg[34].

PFOS exists in the environment as the anionic moiety and may partition in organisms by binding to proteins (in the blood and liver) rather than by hydrophobic interactions with lipids[25]. The propensity of PFOS to bioaccumulate in aquatic animals is difficult to estimate because of the unusual properties of the molecule. In octanol/water tests, PFOS forms three layers, indicating that a log K_{ow} cannot be reliably determined[28], nor be used as a predictor of the potential for PFOS to bioconcentrate. In addition, PFOS has a very low pK_a value (the acid dissociation constant), and readily dissociates in water[25]. Experimental data for Bluegill sunfish (*Lepomis macrochirus*) determined a whole fish BCF value of 2,796 L/kg, while another study assessing Rainbow trout (*Oncorhynchus mykiss*) determined BCFs of 2,900 and 3,100 for blood and liver respectively[22,30].

Bioaccumulation Factors (BAFs) for PFOS in freshwater fish have been reported to range from 2,500 to 95,000 L/kg[24]. PFOS also has high biomagnification potential. Moermond et al.[24] summarised a number of Biomagnification Factor (BMF) studies from the literature, including studies of measured and modelled BMFs. For fish, a BMF value of 5 kg/kg has been presented[24]. The authors concluded that "*biomagnification of PFOS in fish is relevant*" although they suggest that caution is used in interpretation of both measured and predicted BCF and BMF data, given the bioaccumulation potential of PFOS is not reliably predicted using laboratory BCF measurements. BAFs based on laboratory BCFs and default BMFs will under-estimate accumulation.

Studies on PFOS bioaccumulation at higher trophic levels indicate accumulation in particular organs (such as liver tissues)[3,13]. Fish-eating organisms have been found to contain greater concentrations of PFOS than their food sources[22]. Concentrations of PFOS between 2 and 72.9 μg/g were reported in fish liver samples following an accidental release of fire-fighting foam in a Canadian Creek[22]. Concentrations of PFOS in livers of top predators were also elevated. A report prepared by the Swedish Chemicals Inspectorate (KemI) and the Swedish Environmental Protection Agency present a summary of PFOS concentrations in biota including plasma concentrations of PFOS up to 2,570 ng/g in the bald eagle in the US, PFOS concentrations up to 1100 ng/g reported in the livers of seals in Finland, and fish in Belgium with reported concentrations of PFOS up to 923 ng/g wet weight in muscle tissues[34].

2 AQUATIC TOXICOLOGY

A literature review of the effects of PFOS on freshwater organisms indicates reasonably extensive research has been undertaken. The majority of aquatic toxicology studies have been performed using the potassium salt of PFOS, with fewer studies conducted using the acid, lithium or ammonium salts. According to OECD[28], at neutral pH, salts of perfluorooctane sulfonic acid dissociate to release the PFOS anion ($C_8F_{17}SO_3^-$). Consistent with OECD[28], the aquatic toxicology data used to derive the Default Guideline Values (DGVs) have not been converted to the PFOS anion, with the exception of PFOS tetraethyl ammonium salt. It has been assumed that the PFOS anion results in the toxic effect and that the potassium and acid cations do not significantly affect toxicity. The acid, ammonium and metal-salts of PFOS have similar molecular weights (ranging from 500.1 to 538.2 g/mol), compared to the PFOS anion (molecular weight of 499.1 g/mol), whereas the tetraethyl ammonium salt of PFOS has a molecular weight of 629.1 g/mol[24] and hence these data were converted to the PFOS anion.

Numerous acute studies were available assessing mortality due to PFOS exposure. These studies included laboratory tests undertaken on a number of invertebrates including rotifers, flatworms, daphnids, mussels, shrimp and snails, and to a lesser extent on fish and amphibians. Based on review of over 50 acute endpoints, LC50 values ranged from 4.75 mg/L for the fish *Pimephales promelas* (adults exposed to PFOS for 4 days) to 178 mg/L for the snail, *Physa acuta* (exposed over a 4 day period)[12,19,28]. Other acute endpoints assessed included valve closure in the mussel *Liguma recta* (1-d EC50 13.5 mg/L), malformations in the frog *Xenopus laevis* (4-d EC50 12.1 mg/L), immobility in the daphnid *Daphnia magna* (2-d EC50 0.8 mg/L) and developmental effects in the fish *Danio rerio* (5-d LOEC 0.1 mg/L)[5,12,15,28].

The literature review also identified over 65 chronic endpoints for eighteen species. The geomean, or the lowest chronic endpoint for each species were used to generate the Species Sensitivity Distribution (SSD) and the DGVs. The data used to derive the DGVs represent species of algae[5,20,28], macrophytes[14], crustacean[5,16,19,21,31], insects[3,23], fish[2,13,16,17,27,36] and one species of frog[1]. The most sensitive species were the fish *D. rerio* (F2 generation 180-d growth LOEC of 0.734 μg/L converted to a NOEC equivalent of 0.294 μg/L[17]; and F1 generation 8-d survival NOEC of 5 μg/L[36]) and *Oryzias latipes* (F1 generation 8-d growth LOEC 10 μg/L converted to a NOEC equivalent of 4 μg/L)[16], the damselfly *Enallagma cypathigerum* (120-d emergence NOEC 10 μg/L)[3], and the daphnid *D. magna* (21-d growth NOEC 8 μg/L)[21]. The range of endpoints for the species assessed included survival, growth and reproduction with lower effect concentrations associated with endpoints such as growth and reproduction.

Fish showed greater sensitivity to PFOS with effect concentrations below 300 μg/L (growth NOEC at 24-d for *Pimephales promelas*)[2]. The lowest effect concentration was reported in *D. rerio* (F2 generation 180-d growth LOEC of 0.734 μg/L converted to a NOEC equivalent of 0.294 μg/L)[17]. This study notably exposed eggs 2-4 hours post fertilization, whereas the fry used in the *Xiphorous helleri* (90-d growth LOEC of 100 μg/L converted to a NOEC equivalent of 40 μg/L)[13] were between 20-30 days old at test initiation. The effect on hatching of the F1 generation of *O. latipes* (8-d growth LOEC 10 μg/L converted to a NOEC equivalent of 4 μg/L)[16] represented a second generation effect, following exposure of the parental F0 generation to PFOS for 14 days.

Aquatic toxicology tests have limited capacity to measure effects relating to contaminant bioaccumulation, endocrine disruption, and multigenerational effects. A limited number of two-generation or multigenerational studies[2,9,16,36] with fish exposed to PFOS were found during the literature review. These studies reported effects (such as changes in sex steroid levels and histopathological changes to ovarian cells) which provide supporting evidence of adverse effects from PFOS in subsequent generations.

There is a paucity of data on the effects of PFOS on amphibians, however, one chronic frog study on survival and development in *Rana pipiens* was included in the SSD based on a 5 week LC50 value of 6,210 μg/L converted to a NOEC equivalent of 1,242 μg/L[1].

3 FACTORS AFFECTING TOXICITY

To date, there is no evidence to suggest there are factors affecting the toxicity of PFOS to freshwater aquatic organisms.

4 GUIDELINE DERIVATION

The DGVs for PFOS in freshwater are provided in Table 1.

The numerical protection levels for PFOS in freshwater ecosystems have been derived for aquatic organisms according to the procedures outlined in the *Revised Method for Deriving Australian and New Zealand Water Quality Guideline Values for Toxicants*. These methods are not intended to specify species protection concentrations for air-breathing animals which live in aquatic ecosystems, or prey on aquatic organisms. The default guideline values for aquatic ecosystems may not account for effects which result from the biomagnification of toxicants such as PFOS in air breathing animals.

The DGV for PFOS is defined as of "very high" reliability according to the Revised Method for Deriving Australian and New Zealand Water Quality Guideline Values for Toxicants. However, because the data span greater than four orders of magnitude, there is greater uncertainty, and lower confidence in the 99% species protection level. The 99% species protection level may be near or below analytical detection limits.

Table 1 Default guideline values (µg/L) for PFOS for the protection of freshwater ecosystems.

PFOS default guideline values; freshwater[a]	
Percent species protection	**Concentration (*µg/L*)**
99%	0.00023
95%	0.13
90%	2.0
80%	31

Reliability classification[b]	
Criterion	**Result**
Sample size	18
Type of toxicity data	Chronic
SSD model fit	Good
Reliability	Very High

[a] Guideline values were derived using the Burrlioz 2.0® software.

[b] See Warne et al (2014) for definitions of guideline value "reliability".

TOXICITY DATA USED IN DERIVATION

A summary of the toxicity data and conversions used to derive the DGVs are provided in Table 2. Further details about the data and test conditions are given in Attachment A.

Eighteen chronic data from five taxonomic groups (algae, crustaceans, insects, fish and amphibians) were available. Of these 18 chronic endpoints, six were EC10/IC10 endpoints, and eight were NOECs. EC10/IC10 and NOECs are preferred endpoints that require no conversion. Three chronic LOEC endpoints were converted to NOEC equivalents by dividing by a default factor of 2.5. One chronic LC50 endpoints was similarly converted by dividing by the default factor of 5. In all, 18 chronic NOECs or NOEC-equivalents were used to derive the DGV.

Professional judgements were applied in the DGV and entail: use of chronic LOEC and LC50 endpoints for fish and frogs even though there were sufficient chronic NOEC or EC10 end points for generating the SSD; and selection of the *D. rerio* endpoint. The converted LOEC/LC50 values were from studies where chronic, partial or full-life cycle exposure of higher trophic level organisms occurred which is considered appropriate for a highly PBT chemical such as PFOS. The *D. rerio* endpoint from a multigenerational study[17] was used in preference to an F1 endpoint from a two-generational study[36] for the same species. The lower effect concentration (F2 generation 180-d growth LOEC of 0.734 µg/L converted to a NOEC equivalent of 0.294 µg/L) [17] was selected for the SSD.

In the chronic toxicity dataset, the least sensitive species were the algae (both micro[5,28] and macro[14]). The effects concentration for cell density varies between species, with concentrations ranging from 5,300 µg/L for *Selenastrum capricornutum*[5] (4-d NOEC) to 82,000 µg/L for the same endpoint and same duration for *Anabaena flos-aquae*[28]. A check for modality was performed and a comparison of animals to plants indicated bi-modality, with plants less sensitive to PFOS exposure than animals (statistically significantly different, P=0.003). The mode of action of PFOS is not yet fully described. Modes of action for PFOS that were found in the literature are speculative and include: activation of the nuclear peroxisome proliferator activated receptor-alpha (PPAR-α)[3,4]; uncoupling of oxidative phosphorylation[24]; inhibition of intercellular gap junctions[24]; endocrine effects[1,3]; interaction with transporter proteins[17]. The speculated MOA are relevant to all groups of receptors. As there is no confirmed mode of action for PFOS to explain the apparent differences in toxic effect between animals and plants, plants were retained in the PFOS dataset used to generate the SSD.

SPECIES SENSITIVITY DISTRIBUTION

The cumulative frequency (species sensitivity) distribution of the 18 chronic freshwater PFOS toxicity data reported in Table 2 is shown in Figure 1.

Table 2 Summary of chronic toxicity data values used to derive the default guideline values for PFOS

Taxonomic group	Species	Life stage	Duration (h)	Type (acute/ chronic)	Toxicity measure[a]	Toxicity value (µg/L)	Estimated chronic NOEC (µg/L)
Micro Algae	*Selenastrum capricornutum*	-	96	Chronic	NOEC	5,300	5,300[a]
	Chlorella vulgaris	-	96	Chronic	NOEC	8,200	8,200[a]
	Scenedesmus obliquus	-	72	Chronic	IC10	51,000	51,000[b]
	Navicula pelliculosa	-	96	Chronic	EC10	62,300	62,300[b]
	Anabaena flos-aquae	-	96	Chronic	EC10	82,000	82,000[b]
Macrophyte	*Myriophyllum sibiricum*	-	1,008	Chronic	EC10	100	100[b]
	Myriophyllum spicatum	-	672	Chronic	EC10	3,300	3,300[b]
	Lemna gibba	-	168	Chronic	NOEC	6,600	6,600[a]
Crustacean	*Daphnia magna*	Neonates	504	Chronic	NOEC	8	8[a]
	Moina macrocopa	Neonates	168	Chronic	NOEC	312.5	312.5[a]
	Daphnia pulicaria	Neonates	504	Chronic	NOEC	6,000	6,000[a]
Insecta - Odonata	*Enallagma cyathigerum*	Larvae	2,880	Chronic	NOEC	7.95	7.95[a]
Insecta – Diptera	*Chironomus tentans*	Larvae	240	Chronic	EC10	49.2	49.2[b]
Fish	*Danio rerio*	F2, Eggs-embryos	4,320	Chronic	LOEC	0.734	0.294[c]
	Oryzias latipes	F1, Eggs-embryos	192	Chronic	LOEC	10	4[c]
	Xiphorous helleri	Fry/Larvae	2,160	Chronic	LOEC	100	40[c]
	Pimephales promelas	Fry/Larvae	576	Chronic	NOEC	300	300[a]
Amphibian	*Rana pipiens*	Eggs	840	Chronic	LC50	6,210	1,242[d]

The measure of toxicity being estimated/determined: NOEC: No observed effect concentration; LOEC: Lowest observed effect concentration; LC_{50}: median lethal concentration; EC_{10}: 10% effects concentration; IC10: 10% inhibition concentration

[a] Actual NOEC

[b] No conversion from EC/IC_{10} to NOEC required

[c] Converted from chronic LOEC (NOEC = LOEC/2 5)

[d] Converted from chronic LC_{50} (NOEC = LC_{50}/5)

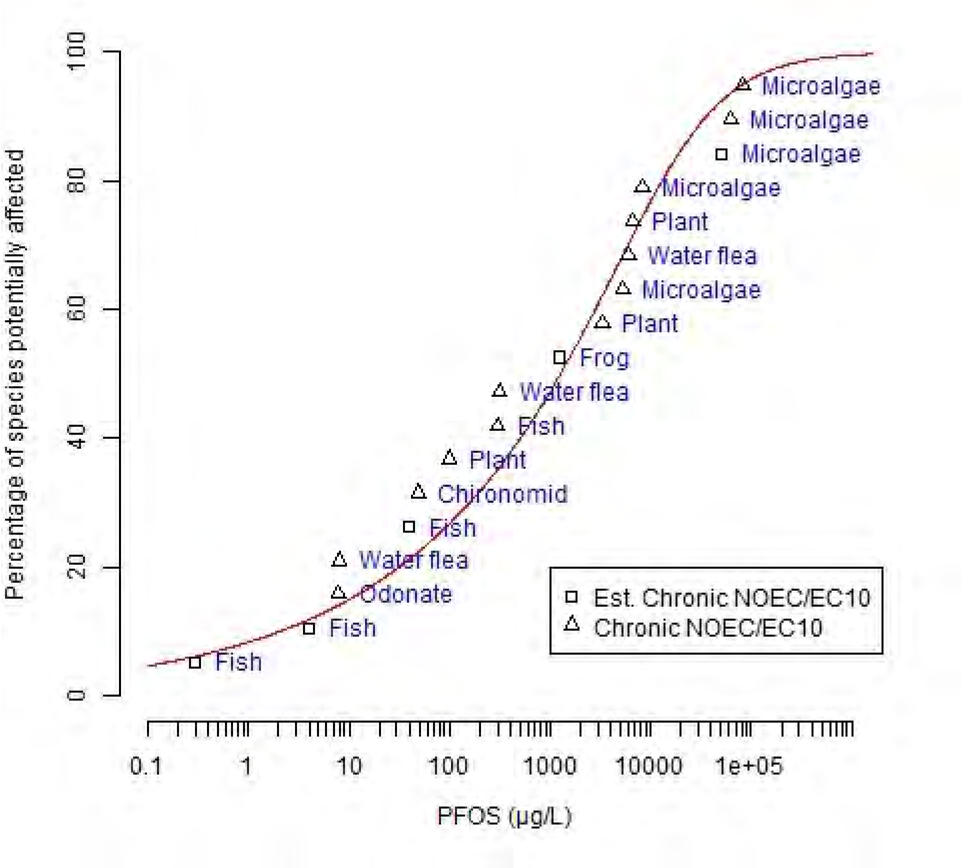

Figure 1 Cumulative frequency distribution (from Burrlioz 2.0©) for PFOS freshwater chronic toxicity (chronic NOEC, IC10, EC10, and converted chronic LOEC, LC50 data (µg/L).

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GLOSSARY, ACRONYMS AND ABBREVIATIONS

Acute toxicity	An adverse effect that occurs as the result of a short exposure period to a chemical relative to the organism's life span.
BAF (Bioaccumulation Factor)	Bioaccumulation is the process by which chemical substances are accumulated by organisms by all routes of exposures i.e., dietary and the ambient environment. Bioaccumulation is the net result of competing processes of chemical uptake into the organism at the respiratory surface and from the diet and chemical elimination from the organism including respiratory exchange, fecal egestion, metabolic biotransformation. The degree to which bioaccumulation occurs can be expressed as a bioaccumulation factor (BAF), at steady state. The BAF can be expressed on wet weight, dry weight, and lipid weight bases. Most commonly, the weight of the organism is presented on a wet weight basis and the units of the BAF are L/kg.
BCF (Bioconcentration Factor)	Describes the degree to which a chemical can be concentrated in the tissues of an organism in the aquatic environment via absorption through the respiratory and dermal surfaces i.e. dietary exposure is excluded. It is the net result of competing rates of chemical uptake at the respiratory surface (e.g., gills in fish) and chemical elimination. At apparent equilibrium, the BCF is the concentration of a chemical in one or more tissues of the aquatic organisms divided by the average exposure concentration in the test, expressed in units of L/kg.
BMF (Biomagnification Factor)	Biomagnification is a process in which the thermodynamic activity of the chemical in an organism exceeds that of its diet and is expressed by a biomagnification factor (BMF). The BMF is the ratio of contaminant concentration in in an organism to that in its diet at steady state. BMF can be expressed on a wet weight basis or dry weight basis, or as a fugacity ratio. For substances that appear to predominantly accumulate associated with proteins (e.g., perfluorooctane sulfonate or PFOS), concentrations can be expressed on a protein normalized basis or protein weight basis.
CASRN	Chemical Abstracts Service Registry Number
Chronic toxicity	An adverse effect that occurs as the result of exposure to a chemical for a substantial portion of the organism's life span or an adverse sub-lethal effect on a sensitive early life stage.
Default guideline value (DGV)	A guideline value recommended for generic application in the absence of a more specific guideline value (e.g. site-specific), in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality
EC_{50} (median effective concentration)	The concentration of material in a medium that is estimated to be effective in producing some lethal or growth response in 50% of the test organisms. The EC_{50} is usually expressed as a time-dependent value (e.g. 24-hour or 96-hour EC_{50}).
Endpoint	Measured attainment response, typically applied to ecotoxicity or management goals
Guideline value (GV)	A measurable quantity (e.g. concentration) or condition of an indicator for a specific environmental value below which (or above which, in the case of stressors such as pH, dissolved oxygen and many biodiversity responses) there is considered to be a low risk of unacceptable effects occurring to that environmental value. Guideline values for more than one indicator should be used simultaneously in a multiple lines of evidence approach.

K_{ow}	The octanol-water partition coefficient (K_{ow}) is the ratio of the solubility of a chemical in octanol divided by its solubility in water. It is a measure of the preference for a substance to dissolve in an organic solvent or water and is used as a measure of lipophilicity and movement of a substance across a cell membrane. It is usually expressed in the logarithmic form (Log K_{ow}). It can be used to estimate environmental fate and transport of a chemical.
LC_{50}	Median lethal concentration
LOEC (Lowest observed effect concentration)	The lowest concentration of a material used in a toxicity test that has a statistically significant adverse effect on the exposed population of test organisms as compared with the controls.
NOEC (No observed effect concentration)	The highest concentration of a toxicant at which no statistically significant effect is observable, compared to the controls; the statistical significance is measured at the 95% confidence level.
PBT	Persistent, Bioaccumulative and Toxic
PFAS	Perfluoroalkyl and polyfluoroalkyl substances, containing the perfluoroalkyl moiety
PFOS	Perfluorooctane sulfonate. PFOS anion: Perfluorooctane sulfonate (1-Octanesulfonate, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-, CASRN: N/A, Molecular Formula: $C_8F_{17}SO_3^-$)
POPs (Persistent Organic Pollutants)	As defined under the Stockholm Convention, POPs are organic compounds that possess toxic properties, resist degradation, bioaccumulate and are transported, through air, water and migratory species, across international boundaries and deposited far from their place of release, where they accumulate in terrestrial and aquatic ecosystems.
Species	A group of organisms that resemble each other to a greater degree than members of other groups and that form a reproductively isolated group that will not produce viable offspring if bred with members of another group.
SSD	Species Sensitivity Distribution
Toxicity	The inherent potential or capacity of a material to cause adverse effects in a living organism.

ATTACHMENT A. *Full details of chronic toxicity data used to derive PFOS (fresh) guideline values*

Phyla/Division	Species	Life stage	Exposure duration (h)	Test type	Toxicity measure [a] (Test Endpoint)	Test medium	Temp. (°C)	Salinity (‰)	pH	Conc (µg/L)	Reference
Chlorophyta	Cyanobacteria (blue-green algae) *Anabaena flos-aquae*	-	96	Chronic	EC10 (Growth rate)	Reverse osmosis-purified well water with culture medium	22.8 – 23.8°C	-	7.4–7.6	**82,000** [b]	OECD (2002)
	Green algae *Chlorella vulgaris*	-	96	Chronic	NOEC (Growth - Cell Density)	Bristol's algal growing media	23±1°C	-	-	**8,200** [b]	Boudreau et al. (2003)
	Green algae *Chlorella vulgaris*	-	96	Chronic	NOEC (Growth - Chlorophyll a)	Bristol's algal growing media	23±1°C	-	-	9,600 [b]	Boudreau et al. (2003)
	Navicula pelliculosa	-	96	Chronic	EC10 (Growth - Cell Density)	Reverse osmosis-purified well water with culture medium	23.1-24.6°C	-	7.5-8.6	**62,300** [b]	OECD (2002)
	Scenedesmus obliquus	-	72	Chronic	IC10 (Growth - Fluorescence)	Algal media	22±1°C	-	7.5±o.2	**51,000** [c]	Liu et al. (2008)
	Scenedesmus obliquus	-	72	Chronic	IC10 (Growth – Optical Density	Algal media	22±1°C	-	7.5±o.2	55,000 [c]	Liu et al. (2008)
	Selenastrum capricornutum (Pseudokirchneriella subcapitatum)	-	96	Chronic	NOEC (Growth - Cell Density)	Bristol's algal growing media	23±1°C	-	-	**5,300** [b]	Boudreau et al. (2003)

Phyla/Division	Species	Life stage	Exposure duration (h)	Test type	Toxicity measure[a] (Test Endpoint)	Test medium	Temp. (°C)	Salinity (‰)	pH	Conc (µg/L)	Reference
	Selenastrum capricornutum (Pseudokirchneriella subcapitatum)	-	96	Chronic	NOEC (Growth - Chlorophyll a)	Bristol's algal growing media	23±1°C	-	-	16,600[b]	Boudreau et al. (2003)
Spermatophyta	Common water milfoil *Myriophyllum sibiricum*	-	1,008	Chronic	EC10 (Growth – root length)	Irrigation pond water	-	-	-	**100**[b]	Hanson et al. (2005)
	Eurasian water milfoil *Myriophyllum spicatam*	-	672	Chronic	EC10 (Growth – biomass)	Irrigation pond water	-	-	-	**3,300**[b]	Hanson et al. (2005)
Tracheophyta	Duckweed *Lemna gibba*	-	168	Chronic	NOEC (Wet Weight)	Hunter's growing media	25±1°C	-	-	**6,600**[b]	Boudreau et al. (2003)
Tracheophyta	Duckweed *Lemna gibba*	-	168	Chronic	NOEC (Frond number)	Hunter's growing media	25±1°C	-	-	29,200[b]	Boudreau et al. (2003)
Chordata	Zebra fish *Danio rerio*	F2, Eggs-embryos	2,160	Chronic	LOEC (Growth – length and weight - males)	Tap water and deionized water	26±1°C	-	8.25-8.75	0.734[b]	Keiter et al. (2012)
	Zebra fish *Danio rerio*	F2, Eggs-embryos	4,320	Chronic	LOEC (Growth – length and weight - females)	Tap water and deionized water	26±1°C	-	8.25-8.75	**0.734**[b]	Keiter et al. (2012)
	Fathead minnow *Pimephales promelas*	Fry	576	Chronic Growth	NOEC	Lake Superior water	25°C	-	7.3	**300**[b]	Ankley et al. (2005)

Phyla/Division	Species	Life stage	Exposure duration (h)	Test type	Toxicity measure [a] (Test Endpoint)	Test medium	Temp. (°C)	Salinity (‰)	pH	Conc (µg/L)	Reference
	Fathead minnow *Pimephales promelas*	Fry	576	Chronic Survival	NOEC	Lake Superior water	25°C	-	7.3	300 [b]	Ankley et al. (2005)
	Fathead minnow *Pimephales promelas*	Adult	672	Chronic	LC10	Pond water	22.7±0.3°C	-	8.9-10.9	3,500 [b]	Oakes et al. (2005)
	Green swordtail *Xiphorus helleri*	Fry	2,160	Chronic	LOEC	Dechlorinated tap water	27 ±1°C	-	-	**40** [b]	Han and Fang (2010)
	Japanese rice fish, Medaka *Oryzias latipes*	F1, Eggs-embryos	192	Chronic	LEOC	Dechlorinated tap water	25°C	-	-	**10** [c]	Ji et al., (2008)
	Northern leopard frog *Rana pipiens /Lithobates pipiens*	Embryo-tadpole	840	Chronic	LC50	Lake Superior water	20°C	-	-	**6,210** [b]	Ankley et al. (2004)
Arthropoda (Crustacea)	Non-biting midge *Chironomus tentans*	Larvae	240	Chronic	EC10 (Growth)	ASTM Hard water	23°C	-	-	**49.2** [b]	MacDonald et al. (2004)
	Non-biting midge *Chironomus tentans*	Larvae	480	Chronic	EC10 (Mortality)	ASTM Hard water	23°C	-	-	86.4 [b]	MacDonald et al. (2004)

Phyla/Division	Species	Life stage	Exposure duration (h)	Test type	Toxicity measure [a] (Test Endpoint)	Test medium	Temp. (°C)	Salinity (‰)	pH	Conc (µg/L)	Reference
	Non-biting midge *Chironomus tentans*	Larvae	480	Chronic	EC10 (Growth)	ASTM Hard water	23°C	-	-	88.2 [b]	MacDonald et al. (2004)
	Non-biting midge *Chironomus tentans*	Larvae	480	Chronic	EC10 (Total emergence)	ASTM Hard water	23°C	-	-	89.3 [b]	MacDonald et al. (2004)
	Moina macrocopa	Neonates	168	Chronic	NOEC (Reproduction)	Moderately Hard water	25±1°C	-	-	**312.5** [c]	Ji et al., (2008)
	Enallagma cyathigerum	Eggs	336	Chronic	NOEC (Hatching success)	Dechlorinated Tap water	21°C	-	-	7,950 [d]	Bots et al. (2010)
	Enallagma cyathigerum	Eggs	336	Chronic	NOEC (Hatching time)	Dechlorinated Tap water	21°C	-	-	7,950 [d]	Bots et al. (2010)
	Enallagma cyathigerum	Larvae	2,880	Chronic	NOEC (Larval survival)	Dechlorinated Tap water	21°C	-	-	**7.95** [d]	Bots et al. (2010)
	Enallagma cyathigerum	Larvae	2,880	Chronic	NOEC (Larval development time)	Dechlorinated Tap water	21°C	-	-	7.95 [d]	Bots et al. (2010)
	Enallagma cyathigerum	Larvae	2,880	Chronic	NOEC (Metamorphosis success)	Dechlorinated Tap Water	21°C	-	-	7.95 [d]	Bots et al. (2010)
	Daphnia pulicaria	Neonates	504	Chronic	NOEC (Mortality)	Laboratory grade distilled water	21±1°C	-	-	**6,000** [b]	Boudreau et al. (2003)
	Daphnia magna	Neonates	504	Chronic	NOEC (Mortality)	Laboratory grade distilled water	21±1°C	-	-	5,300 [b]	Boudreau et al. (2003)

Phyla/Division	Species	Life stage	Exposure duration (h)	Test type	Toxicity measure [a] (Test Endpoint)	Test medium	Temp. (°C)	Salinity (‰)	pH	Conc (µg/L)	Reference
	Daphnia magna	Neonates	504	Chronic	NOEC (Mortality)	ASTM medium	20±1°C	-	-	5,000 [b]	Li (2010)
	Daphnia magna	Neonates	504	Chronic	NOEC (Mortality)	Moderately Hard clean well water	21±1°C	-	-	25,000 [e]	Sanderson et al. (2004)
	Daphnia magna	Neonates	504	Chronic	NOEC (Reproduction)	ASTM medium	20±1°C	-	-	1,000 [b]	Li (2010)
	Daphnia magna	Neonates	504	Chronic	NOEC (Reproduction)	Moderately Hard water	21±1°C	-	-	1,250 [c]	Ji et al., (2008)
	Daphnia magna	Neonates	504	Chronic	NOEC (Growth – body length)	Daphnia culture media	20±1°C	-	7.3±0.3	8 [f]	Lu et al. (2015)

[a] The measure of toxicity being estimated/determined: EC10: the concentration resulting in effects to 10% of the test organisms; LC10: the lethal concentration for 10% of the test organisms; LC50: median lethal concentration; LOEC: Lowest Observed Effect Concentration; NOEC: No observed effect concentration.

[b] The test substance was the PFOS potassium salt.

[c] PFOS acid (Perfluorooctane sulfonic acid)

[d] PFOS tetraethyl-ammonium salt

[e] Reported as the PFOS anion ($C_8F_{17}SO_3^-$)

[f] PFOS form not stated, assumed to be the anion

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Document 19

FOOD STANDARDS Australia New Zealand
Te Mana Kounga Kai – Ahitereiria me Aotearoa

Summary of Consolidated Report

Perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA) and perfluorohexane sulfonate (PFHxS) belong to a group of compounds referred to as per- and poly-fluoroalkylated (PFAS) substances.

The use of these chemicals in firefighting foams has led to contamination in some Australian locations.

The Australian Department of Health asked Food Standards Australia New Zealand (FSANZ) to review interim health based guidance values (HBGVs) for PFOS and PFOA developed by the Environmental Health Standing Committee (enHealth)[1]—a subcommittee of the Australian Health Protection Principal Committee. FSANZ also reviewed PFHxS, providing advice about potential dietary risks associated with food and considered risk management options.

FSANZ looked at comprehensive international assessments on the health effects of PFAS and recommended tolerable daily intakes (TDIs) of 20 ng/kg bw/day for PFOS and 160 ng/kg bw/day for PFOA.[2] There was not enough information to establish a TDI for PFHxS.

There is very little data on the occurrence of these compounds in the general food supply so it not possible to calculate dietary exposure for the general Australian population. However, based on the data that is available and a literature review, dietary exposure to PFOS, PFOA and PFHxS from the general food supply is likely to be low.

People consuming certain foods sourced from or near contaminated sites may reach the TDI for PFOS and PFOS/PFHxS combined when they consume their usual amounts of that food but not for PFOA. Foods that result in the greatest potential exposure include cattle meat, rabbit meat, milk, offal and some vegetables. However, there are data limitations, so FSANZ's conclusions are highly conservative. It is also extremely unlikely that the specific foods consumed (e.g. milk and milk products) over a period would all be sourced locally from a contaminated site.

FSANZ considered a range of regulatory and non-regulatory options in parallel with at-site risk management measures by other commonwealth and state and territory jurisdictions to manage and potentially reduce dietary exposure of PFAS.

Whilst there are insufficient data to recommend a regulatory approach and set maximum limits in the Food Standards Code, FSANZ proposed trigger points for investigation for PFOS + PFHxS combined and PFOA. These trigger points could be employed by state and territory food jurisdictions when analysing PFAS in foods to identify when further investigation of a food may be required. For example, when levels of PFAS in analysed foods exceed specific values (trigger points) further investigations or risk management action may be required but this would be dependent on the relevant jurisdiction and the specific issues at the particular site.

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[1] Enhealth adopted the 2008 European Food Safety Authority (EFSA) human health reference values for two PFAS chemicals, perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) and set interim Health Based Guidance Values (HBGVs).

[2] These values are lower than the EFSA TDIs of 150 and 1,500 ng/kg bw/day, respectively.

Summary of environmental and health research programs funded by the Australian Government

Epidemiological study

The Australian Government has commissioned the National Centre for Epidemiology and Population Health at the Australian National University (ANU) to examine the potential health effects resulting from PFAS exposure through an epidemiological study. This study is being run concurrently with the Voluntary Blood Testing Program, which is provided for people who live or work, or who have lived or worked in the Williamtown, NSW, Management Area, and Oakey, Qld, Investigation Area.

The ANU research team will collect details of PFAS exposure, health profiles and results of the PFAS blood testing. This will allow comparison with communities without a history of PFAS contamination.

Per- and Poly-fluorinated Alkyl Substances – National Health Research Program

This is a national research program into the human health effects of PFAS. The aim is to increase the evidence and understanding of potential human health effects from prolonged exposure to PFAS.

The National Health and Medical Research Council (NHMRC) will administer the program, with grant funding to be delivered to researchers through a call for proposals.

In November 2017, the Expert Health Panel was established to review the current literature on potential health effects of PFAS exposure and identify priority areas for research. The Panel will provide its advice on priority research areas to the NHMRC for the program.

PFAS Research Remediation Grants Program

The Department of Defence has provided $15 million seed funding to establish this remediation program, to be administered by the Australian Research Council. The program will fund research to develop effective technologies that can be applied to remediate PFAS contaminated soil, waterways, waste, debris and/or large volumes of groundwater, and develop options and mechanisms through which these effective technologies can be applied in the field.

The priority areas for this program are:

- Practical technologies for application in the field
- End-to-end and/or modular remediation processes
- Technologies for waste, water, soil and sediment remediation
- Technologies applicable to PFAS affecting the chosen media, in particular PFOS, PFOA, PFHxS and precursors

Whole of Australian Government achievements in 2017

During 2017, the PFAS Taskforce chaired the PFAS Interdepartmental Committee (IDC), which includes representation from thirteen Australian Government agencies. Over the last twelve months, the Taskforce and IDC agencies have worked together (and in close collaboration with states and territories where appropriate) to deliver the following:

- A number of policy options for Cabinet consideration (led by the Taskforce);
- An Intergovernmental Agreement on a National Framework for Responding to PFAS Contamination (the National Framework), to be taken to COAG for endorsement in early 2018 (Taskforce – see below for more information);
- The PFAS National Environmental Management Plan (Department of the Environment and Energy);
- Working on management options for a phase out of PFOS and related compounds as part of Government's decision-making on ratifying amendments to the Stockholm Convention on Persistent Organic Pollutants (Department of the Environment and Energy);
- A National Remediation Research Program (Taskforce, Department of Defence, Department of Industry, Australian Research Council);
- A National Research Program into the Human Health Effects of Prolonged Exposure to PFAS, informed by public submissions and an Expert Panel (Department of Health);
- An epidemiological study, linked with a voluntary blood testing program, focusing on people who lived and worked in Williamtown and Oakey (Department of Health);
- A comprehensive report by FSANZ[1] that provides Health Based Guidance Values for site investigations, a dietary exposure assessment, and risk management advice for authorities investigating PFAS contamination (Department of Health);
- A Whole of Australian Government Approach for Assessing and Responding to PFAS Contamination (Taskforce);
- Whole of Australian Government Communication and Engagement Guidelines (Taskforce);
- Ongoing preliminary and detailed site investigations (Department of Defence, Airservices Australia);
- Numerous community engagement and consultation activities (Departments of Defence, Infrastructure and Regional Development, Health, Environment and Energy, Agriculture and Water Resources, Human Services, and Airservices Australia);
- A stocktake of sites currently owned, managed or leased by the Commonwealth, and identified stockpiles of PFAS containing products (Taskforce, with input from all Commonwealth agencies); and
- Engagement with the banking sector, property valuers, insurance representatives, and local government, to provide information on PFAS contamination and Government responses (Taskforce).

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[1] FSANZ = Food Standards Australia New Zealand. FSANZ develops and sets food standards which become part of food law in the Australian states and territories, and New Zealand.