

Short-chain perfluorocarboxylic acids and their direct precursors: Environment tier II assessment

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CAS Registry Numbers: 307-24-4, 21615-47-4, 2706-90-3, 68259-11-0, 375-22-4, 336-59-4.



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Preface

This assessment was carried out by staff of the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) using the Inventory Multi-tiered Assessment and Prioritisation (IMAP) framework.

The IMAP framework addresses the human health and environmental impacts of previously unassessed industrial chemicals listed on the Australian Inventory of Chemical Substances (the Inventory).

The framework was developed with significant input from stakeholders and provides a more rapid, flexible and transparent approach for the assessment of chemicals listed on the Inventory.

Stage One of the implementation of this framework, which lasted four years from 1 July 2012, examined 3000 chemicals meeting characteristics identified by stakeholders as needing priority assessment. This included chemicals for which NICNAS already held exposure information, chemicals identified as a concern or for which regulatory action had been taken overseas, and chemicals detected in international studies analysing chemicals present in babies' umbilical cord blood.

Stage Two of IMAP began in July 2016. We are continuing to assess chemicals on the Inventory, including chemicals identified as a concern for which action has been taken overseas and chemicals that can be rapidly identified and assessed by using Stage One information. We are also continuing to publish information for chemicals on the Inventory that pose a low risk to human health or the environment or both. This work provides efficiencies and enables us to identify higher risk chemicals requiring assessment.

The IMAP framework is a science and risk-based model designed to align the assessment effort with the human health and environmental impacts of chemicals. It has 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.

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

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

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

Disclaimer

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Acronyms & Abbreviations

Grouping Rationale

This Tier II assessment considers the environmental risks associated with the industrial uses of three homologous short-chain perfluorocarboxylic acids and their direct precursors:

Hexanoic acid, undecafluoro- (PFHxA)
Hexanoic acid, undecafluoro-, ammonium salt (ammonium PFHxA)
Pentanoic acid, nonafluoro- (PFPeA)
Pentanoic acid, nonafluoro-, ammonium salt (ammonium PFPeA)
Butanoic acid, heptafluoro- (PFBA)
Butanoic acid, heptafluoro-, anhydride (PFBA anhydride)

The chemicals in this group are short-chain perfluorinated chemicals containing three to five perfluorinated carbons, terminated with a carboxylate group. The chemicals in this group are expected to hydrolyse and/or dissociate into the perfluorohexanoate anion, perfluoropentanoate anion, or perfluorobutanoate anion, respectively, in the aquatic environment.

The chemicals in this group appear to have limited current industrial use. However, these chemicals have been noted internationally due to their extreme persistence in the environment. Further, the homologous long-chain perfluorinated acid, perfluorooctanoic acid (PFOA), has been found to also bioaccumulate and have intergenerational developmental toxicity. Perfluorooctanoic acid (and its ammonium salt) have been categorised as persistent, bioaccumulative and toxic (PBT) substances according to domestic environmental hazard criteria (NICNAS, 2015a).

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 perfluorooctanoic acid is used to estimate the hazard of perfluorocarboxylic acid (PFCA) 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, 2015b).

Perfluorinated and polyfluorinated substances with shorter chains have been developed and used by industry as alternatives to the long-chain perfluorocarboxylic acids (OECD, 2013a). Environmental data for perfluorohexanoic acid (PFHxA) are available; therefore, a toxicity profile that can be compared with that of PFOA can be developed for the members of this group, noting that the toxicity and bioaccumulation potential of PFCAs are expected to decrease with a decrease in chain length. The risks arising from PFHxA and the other chemicals in this group need to be considered in light of the risks of other chemicals such as PFOA when introduced for similar uses.

This assessment will evaluate:

- a) the properties of the chemicals in this group and compare them with PFOA; and
- b) whether there are sufficient data to use in place of the default assumptions in the action plan.

It is noted that whilst the action plan does not apply to PFBA and its anhydride as they do not include a chain of four perfluorinated carbon atoms, PFBA could be formed by the degradation of indirect precursors of PFCAs (to be assessed separately (see below)) with four perfluorinated carbon atoms. In addition, data for PFBA can be used to help infer the properties of the intermediate perfluoropentanoic acid.

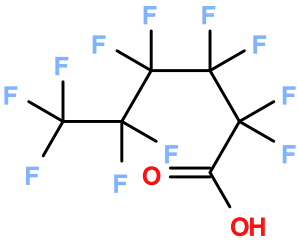
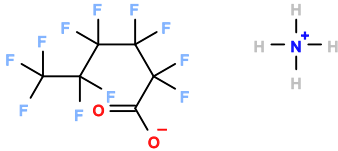
Perfluoroheptanoic acid (PFHpA) and its salts have not been included in this group. No toxicity information is available for PFHpA and it is not considered appropriate to extrapolate from PFHxA. The default position of using hazard information derived from PFOA therefore applies for this chemical and it will be assessed separately.

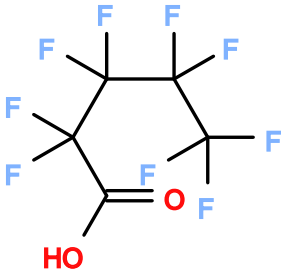
The assessment of these chemicals as a group also provides additional relevant information for the risk assessment of more complex per- and poly-fluorinated substances which may degrade to these short-chain PFCAs in the environment.

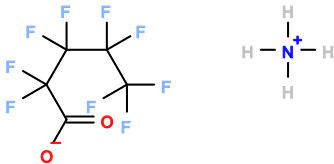
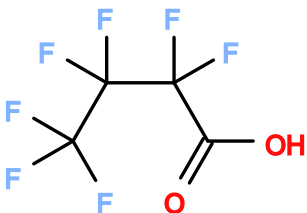
Chemical Identity

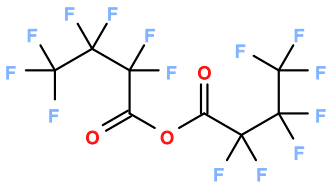
In this assessment, "PFHxA" is used to denote perfluorohexanoic acid and its conjugate base anion (i.e. the perfluorohexanoate anion), "PFPeA" is used to denote perfluoropentanoic acid and its conjugate base anion (i.e. the perfluoropentanoate anion), and "PFBA" is used to denote perfluorobutanoic acid and its conjugate base anion (i.e. the perfluorobutanoate anion) (Buck, et al., 2011).

CAS RN	307-24-4
Chemical Name	Hexanoic acid, undecafluoro-
Synonyms	PFHxA perfluorohexanoic acid undecafluorohexanoic acid
Structural Formula	

	
Molecular Formula	C ₆ HF ₁₁ O ₂
Molecular Weight (g/mol)	314.05
SMILES	C(F)(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(=O)O
CAS RN	21615-47-4
Chemical Name	Hexanoic acid, undecafluoro-, ammonium salt
Synonyms	ammonium PFHxA ammonium perfluorohexanoate ammonium undecafluorohexanoate
Structural Formula	
Molecular Formula	C ₆ H ₄ F ₁₁ NO ₂
Molecular Weight (g/mol)	331.08

SMILES	<chem>C(F)(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(=O)[O-].[NH4+]</chem>
CAS RN	2706-90-3
Chemical Name	Pentanoic acid, nonafluoro-
Synonyms	PFPeA perfluoropentanoic acid perfluorovaleric acid nonafluoropentanoic acid
Structural Formula	
Molecular Formula	$C_5HF_9O_2$
Molecular Weight (g/mol)	264.05
SMILES	<chem>C(F)(F)(F)C(F)(F)C(F)(F)C(F)(F)C(=O)O</chem>
CAS RN	68259-11-0
Chemical Name	Pentanoic acid, nonafluoro-, ammonium salt
Synonyms	ammonium PFPeA

	<p>ammonium perfluoropentanoate</p> <p>ammonium perfluorovalerate</p> <p>ammonium nonafluoropentanoate</p>
Structural Formula	
Molecular Formula	C ₅ H ₄ F ₉ NO ₂
Molecular Weight (g/mol)	281.08
SMILES	C(F)(F)(F)C(F)(F)C(F)(F)C(F)(F)C(=O)[O-].[NH4+]
CAS RN	375-22-4
Chemical Name	Butanoic acid, heptafluoro-
Synonyms	<p>PFBA</p> <p>perfluorobutanoic acid</p> <p>perfluorobutyric acid</p> <p>heptafluorobutanoic acid</p>
Structural Formula	

Molecular Formula	C ₄ HF ₇ O ₂
Molecular Weight (g/mol)	214.04
SMILES	C(F)(F)(F)C(F)(F)C(F)(F)C(=O)O
CAS RN	336-59-4
Chemical Name	Butanoic acid, heptafluoro-, anhydride
Synonyms	PFBA anhydride perfluorobutanoic anhydride perfluorobutyric anhydride heptafluorobutanoic anhydride
Structural Formula	
Molecular Formula	C ₈ F ₁₄ O ₃
Molecular Weight (g/mol)	410.06
SMILES	C(F)(F)(F)C(F)(F)C(F)(F)C(=O)OC(=O) C(F)(F)C(F)(F)C(F)(F)(F)

Physical and Chemical Properties

Available physical and chemical property data for the two end member acids in this group (PFBA and PFHxA), in addition to data for a representative ammonium salt (ammonium PFHxA), are presented below (LMC, 2013; US FDA, 2009):

Chemical	PFBA	PFHxA	Ammonium PFHxA
Physical Form	Liquid	Liquid	Solid
Melting Point	-17.5°C (exp.)	Not available	Not available
Boiling Point	121°C (exp.)	157°C (exp.)	Not available
Vapour Pressure	849 Pa (exp.)	264 Pa (exp.)	8.0×10^{-5} Pa (exp.)

No experimental physical and chemical property data were identified for the C₅ acid, PFPeA, or its ammonium salt, ammonium PFPeA. However, the physico-chemical properties of these chemicals are expected to be intermediate to those of their C₄ and C₆ homologues.

The acids in this group are liquids under ambient conditions. Based on their reported vapour pressures, they are all highly volatile substances. The ammonium salt of PFHxA is a solid under ambient conditions with a low reported vapour pressure. However, it is noted that the ammonium salt of perfluorooctanoic acid (APFO; CAS RN: 3825-26-1), which is also a solid under ambient conditions, sublimates (Kaiser, et al., 2010).

Perfluorinated carboxylic acids are known to be surface-active (NICNAS, 2015a; 2015c; Vierke, et al., 2013). The octanol-water partition coefficient parameter (K_{OW}) is not considered to provide a reliable indicator of the partitioning behaviour of surface-active perfluorinated chemicals in the environment (OECD, 2002) and has not been reported.

Measured water solubility values for these chemicals were not identified, although ammonium PFHxA is reported to be soluble (US FDA, 2009). The measured water solubility of the long-chain homologue, PFOA, and its ammonium salt, are both high at the critical micelle concentration (> 1000 mg/L) (NICNAS, 2015a). Based on these findings, it can be expected that all of the acids and salts in this group are readily soluble in water. This is further supported by the properties of the shortest chain-length homologue, trifluoroacetic acid (CAS RN: 76-05-1), which has a reported water solubility of 10⁶ mg/L (LMC, 2013).

A measured acid dissociation constant (pK_a) of 0.17 at 25°C is available for PFBA, while a measured pK_a of 0.84 at 25°C is available for PFHxA (ENVIRON, 2014; LMC, 2013). However, it is noted that there has been some uncertainty in regards to the acid dissociation constants of perfluorinated carboxylic acids (NICNAS, 2015a; Vierke, et al., 2013). The current weight of evidence suggests that perfluorinated carboxylic acids should be considered strong acids ($pK_a < 1$) in aqueous solution at environmentally relevant concentrations (De Voogt, 2010; Vierke, et al., 2013).

Limited data were identified for the properties of PFBA anhydride. However, the simplest perfluoroalkyl anhydride, trifluoroacetic anhydride (CAS RN: 407-25-0), is known to be a reactive substance that is rapidly hydrolysed (ECHA, 2015a). Based on the reactivity of this analogue substance, PFBA anhydride is expected to be rapidly hydrolysed to PFBA in water.

Import, Manufacture and Use

Australia

Information collected by NICNAS in 2006 indicated PFHxA, PFPeA and their derivatives are not currently imported or manufactured in Australia. However, this information could be incomplete because the call for information did not specifically include the PFCAs group (NICNAS, 2013b).

No specific Australian use, import, or manufacturing information was identified for the remaining chemicals in this group.

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. However, release from these uses is beyond the scope of this assessment.

International

Available information indicates that PFHxA, PFPeA and PFBA anhydride were in use between 1999 and 2002 in Nordic countries (Nordic Council of Ministers, 2015). However, PFHxA is reported to not currently be manufactured for commercial use or used in fluoropolymer production (ENVIRON, 2014).

Similarly, limited current data were identified for the salts in this group. Available information indicates that ammonium PFHxA may find use as a replacement for ammonium perfluorooctanoate in the manufacture of fluorotelomers (Wang, et al., 2013).

Environmental Regulatory Status

Australia

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

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, 2013b).

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

The two salts in this group are listed on the Canadian Domestic Substances List (DSL). During the Categorization of the DSL, both ammonium PFHxA and ammonium PFPeA were found to be Not Persistent (Not P), Not Bioaccumulative (Not B) and Not Inherently Toxic to the Environment (Not iTE) (Environment Canada, 2013a). These chemicals were not prioritised for further assessment. The remaining chemicals in this group are not listed on the DSL (Environment Canada, 2013b).

European Union

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

The chemicals in this group do not belong to any of the chemical classes covered by an Existing Chemical Action Plan and have not been selected for action plan development (US EPA, 2013). They have not been subject to any specific regulatory action (US EPA, 2014).

Environmental Exposure

Direct release of PFHxA, PFPeA, PFBA and their derivatives to the environment as a result of their current industrial uses is considered unlikely, as these chemicals are not expected to have significant use in Australia.

The acids in this group are considered more likely to be released to the environment from the use, disposal and degradation of other perfluorinated and polyfluorinated chemicals. 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 per- and polyfluorinated chemicals listed on the Inventory will be considered separately.

The ammonium cations present as counterions in the salts of this group are ubiquitous, naturally occurring inorganic species that are essential for many biological functions. The environmental fate and effects of this cation is not further considered in this assessment.

Environmental Fate

Dissolution, Speciation and Partitioning

The dissolved conjugate base anions of PFHxA, PFPeA and PFBA are the dominant form of these substances in the aquatic compartment.

The three acids in this group are strong acids and it can be assumed that dissolution of the acid in water will involve dissociation into the conjugate base anion. This will be the predominant species in water under typical environmental conditions. As salts of strong acids, the ammonium salts in this group will dissociate into its constituent ions in water. The anhydride is expected to rapidly hydrolyse and dissociate in water to release the perfluorobutanoate anion. The partitioning (and speciation) behaviour of these chemicals in the aquatic compartment may be further influenced by surface activity of the conjugate base anions (Vierke, et al., 2013).

The conjugate base anions of the acids in this group are not expected to volatilise into the air compartment from water and are generally likely to remain in the water compartment under typical environmental conditions (Vierke, et al., 2013). However, the acids are highly volatile substances and volatilisation of the acids to the air compartment is possible.

Degradation

The chemicals in this group are highly resistant to degradation.

Multiple studies conducted on a range of perfluorinated substances have found no evidence of potential for biodegradation, hydrolysis or aqueous photolysis under environmental conditions (NICNAS, 2015a; 2015c). The applicability of these findings to this group is supported by the work of Sáez et al. (2008), who found a range of perfluorinated substances, including PFHxA, to be non-biodegradable using a closed bottle test similar to OECD Test Guideline (TG) 301 D.

The estimated atmospheric lifetime for the acids in this group based on indirect photo-oxidation by hydroxyl radicals is 130 days (OECD, 2008).

Bioaccumulation

The chemicals in this group are not expected to be 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 (Ng and Hungerbühler, 2014). However, a bioconcentration study conducted on fish using a mixture of perfluorinated carboxylic acids failed to detect accumulation of PFHxA or PFPeA in any tissue samples (Martin, et al., 2003b). A similar study considered accumulation in fish from dietary exposure and found no significant bioaccumulation potential of PFHxA and PFPeA (Martin, et al., 2003a). Although these studies did not consider PFBA, bioaccumulation potential was found to decrease with chain length (Martin, et al., 2003a; Martin, et al., 2003b).

The potential for the C₈ homologue, PFOA, to biomagnify in marine and terrestrial mammals due to comparatively poorer elimination of the chemical in top predators has previously been noted (NICNAS, 2015a). However, observations made in humans, monkeys, rats and mice indicate that the shorter chained PFHxA and PFBA are eliminated much more rapidly than PFOA (Chang, et al., 2008; OECD, 2013a; Russell, et al., 2013). The elimination of PFPeA is expected to be similarly rapid due to its intermediate chain length. This is consistent with trends which generally show a decrease in bioaccumulation potential when the length of the perfluorinated carbon chain is decreased (Ng and Hungerbühler, 2014). Therefore, based on currently available data, the chemicals in this group are expected to have low bioaccumulation potential in mammals.

Transport

The chemicals in this group are globally distributed pollutants.

Numerous studies have identified PFHxA, PFPeA and PFBA in various locations worldwide. The chemicals have been measured in the Arctic Ocean, in Antarctica, and/or in the European Alps (Busch, et al., 2010; Cai, et al., 2012; Kirchgeorg, et al., 2013; Zhao, et al., 2012). The global distribution of perfluorinated carboxylic acids 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 atmospheric transport of acids, transport of anions in surface water or ocean currents, and/or transport of volatile precursors (e.g. fluorotelomer alcohols) (Ellis, et al., 2004; OECD, 2013a).

The relative contribution of chemicals in this group to the total load of short-chain perfluorocarboxylic acids in the environment, especially in remote locations, is still unclear and subject to ongoing research. However, the exceptional environmental persistence and the ubiquity of these acids as contaminants in oceans does indicate at least a potential for long range transport of these substances through oceans.

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 per- and poly-fluorinated chemicals which degrade to these substances in the environment. Available monitoring data have confirmed all of the acids in this group are ubiquitous environmental contaminants.

Monitoring of European River Rhine upstream of significant industrial sources has found PFHxA, PFPeA and PFBA at mean concentrations of 2.00, 3.65 and 1.44 nanograms per litre (ng/L), respectively. However, samples taken from the nearby Scheldt River, downstream of a fluorochemical manufacturing plant, were found to contain PFBA in concentrations as high as 335 ng/L. Concentrations of PFHxA and PFPeA were below 70 ng/L (Möller, et al., 2010). Similar results were obtained from water samples taken in the Upper Mississippi River Basin in the USA. Median concentrations of 1.59, 0.71 and 2.73 ng/L were determined for PFHxA, PFPeA and PFBA, respectively. The maximum concentration of PFBA detected was 458 ng/L (Nakayama, et al., 2010). In Spain, mean concentrations of 2.43, 0.40 and 19.5 ng/L for PFHxA, PFPeA and PFBA, respectively, were obtained from samples taken from the Llobregat River system (Campo, et al., 2015).

Analyses of drinking water samples from Europe, Canada, the USA, Japan, India and China have also detected PFHxA, PFPeA and/or PFBA, with a mean PFBA concentration of 15 ng/L found in the Netherlands (Eschauzier, et al., 2013; Llorca, et al., 2012; Mak, et al., 2009). The prevalence of PFBA compared to other perfluorinated compounds has been noted in all of these studies. In one study PFBA was found to be present at concentrations at least four times higher than those of PFOS, PFOA and PFHxA (Eschauzier, et al., 2013).

Limited Australian monitoring data are available for PFPeA and PFBA. However, PFHxA was recently detected in 100% of samples taken from the Parramatta River (main tributary of Sydney Harbour), with a mean concentration of 2.9 ng/L (Thompson, et al., 2011). Sampling of the Brisbane River catchment following a major flooding event in 2011 also found PFHxA present in water at Somerset Dam, Wivenhoe 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 0.06 and 6.2 ng/L (Gallen, et al., 2014).

Environmental Effects

Effects on Aquatic Life

The chemicals in this group are not expected to have high toxicity to aquatic life.

Acute toxicity

The below ecotoxicity data have been used to characterise the aquatic toxicity of all chemicals in this group. All chemicals in this group are expected to form their respective anion in water. Consequently, it is appropriate to read-across data for the acids to their respective ammonium salt or anhydride. In addition, available data suggest that the toxicity of perfluoroalkyl carboxylic acids decreases with chain length (eg. Barmantlo, et al., 2015). Therefore, data for PFHxA should represent a conservative estimate of toxicity for the shorter chain substances. Nevertheless, measured data for the shorter chain substances have been presented where available.

The following measured median effective concentration (EC50) and median lethal concentration (LC50) values for model organisms across three trophic levels have been identified for (a) PFHxA and (b) PFBA (Barmantlo, et al., 2015; ENVIRON, 2014; US FDA, 2009):

Taxon	Endpoint	Method
Fish	(a) 96 h LC50 > 100 mg/L	Experimental
Invertebrates	(a) 48 h EC50 = 1048 mg/L (b) 48 h EC50 = 5251 mg/L	Experimental <i>Daphnia magna</i> (Water flea) OECD TG 202
Algae	(a) 72 h EC50 = 86 mg/L	Experimental <i>Scenedesmus subspicatus</i> (Green algae) Reduced growth rate observed

Chronic toxicity

The following no-observed-effect-concentration (NOEC) values for model organisms across two aquatic trophic levels have been identified for PFHxA (ENVIRON, 2014):

Taxon	Endpoint	Method
Fish	56 d NOEC \geq 10.1 mg/L	Experimental <i>Oncorhynchus mykiss</i> (Rainbow trout) Hatching success, post-hatch survival, length and weight observed
Algae	72 h NOEC = 50 mg/L	Experimental <i>Scenedesmus subspicatus</i> (Green algae) Reduced growth rate observed

In addition, Barmantlo et al. (2015) studied the chronic toxicity of PFHxA to *Daphnia magna* in a study conducted in accordance with OECD TG 211. While a NOEC value was not available, the 21 day EC50 value of 776 mg/L and associated dose-response relationship indicate very low chronic toxicity.

It is noted that long term intergenerational studies for two C₈ perfluorinated acids (PFOA and perfluorooctanesulfonic acid (PFOS)) have indicated potential for chronic toxicity that may not be identified in standard ecotoxicity tests. These studies suggest effects may manifest in offspring when the parent generation is exposed to the chemical (NICNAS, 2015a; 2015c). No intergenerational studies were identified for any of the chemicals in this group. Nevertheless, it is noted that the developmental toxicity of PFBA in fish is over 100 times lower than that of PFOS (Hagenaars, et al., 2011; NICNAS, 2015c).

Effects on Sediment-Dwelling Life

The chemicals in this group are not expected to have high toxicity to sediment-dwelling life.

No data were available for any of the chemicals in this group. However, toxicity data available for the C₈ homologue PFOA (NICNAS, 2015a) suggest the chemicals in this group will have low toxicity to sediment-dwelling life.

Effects on Terrestrial Life

The chemicals in this group can cause developmental toxicity in some terrestrial organisms at moderate concentrations.

The majority of toxicity testing on terrestrial organisms relevant to the chemicals in this group has been conducted on model organisms to evaluate toxicity in humans. A study conducted with mice found maternal doses of ammonium PFHxA at 175 mg/kg body weight caused a statistically significant increase in stillbirths and post natal mortality in the F₁ generation (NICNAS, 2015d). When considered alongside developmental toxicity data for other perfluorinated carboxylic acids (see NICNAS, 2015d; NICNAS, 2015e), these findings are consistent with abovementioned studies in aquatic organisms which indicate that the chronic toxicity of perfluorinated carboxylic acids decreases with chain length. Further information can be found in the IMAP Tier II Human Health Assessment for Short Chain Perfluorocarboxylic acids and their Direct Precursors (NICNAS, 2015d).

Predicted No-Effect Concentration (PNEC)

A PNEC was not calculated for the chemicals in this group as these substances are not expected to experience significant release to the environment as a result of current industrial use.

Categorisation of Environmental Hazard

The categorisation of the environmental hazards of hexanoic acid, undecafluoro- (PFHxA); hexanoic acid, undecafluoro-, ammonium salt (ammonium PFHxA); pentanoic acid, nonafluoro- (PFPeA); pentanoic acid, nonafluoro-, ammonium salt (ammonium PFPeA); butanoic acid, heptafluoro- (PFBA); and butanoic acid, heptafluoro-, anhydride (PFBA anhydride) according to domestic environmental hazard thresholds is presented below (EPHC, 2009; NICNAS, 2013a):

Persistence

Persistent (P). Based on the non-degradability of perfluorinated carboxylic acids, all chemicals in this group are categorised as Persistent.

Bioaccumulation

Not Bioaccumulative (Not B). Based on the available bioconcentration and bioaccumulation studies, all chemicals in this group are categorised as Not Bioaccumulative.

Toxicity

Not Toxic (Not T). Based on the available measured aquatic ecotoxicity values for PFHxA and PFBA, all chemicals in this group are categorised as Not Toxic.

Summary

Hexanoic acid, undecafluoro-; hexanoic acid, undecafluoro-, ammonium salt; pentanoic acid, nonafluoro-; pentanoic acid, nonafluoro-, ammonium salt; butanoic acid, heptafluoro-; and butanoic acid, heptafluoro-, anhydride are categorised as:

- P
- Not B
- Not T

Risk Characterisation

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

Direct release of the chemicals in this group to the environment as a result of their current industrial uses is considered unlikely, as these chemicals are not expected to have significant use in Australia. However, it is noted that the common perfluorinated carboxylic acid components of the chemicals in this group may be present in the environment due to their release from articles or due to environmental degradation of other chemicals not covered by this assessment. These perfluorinated carboxylic acids are highly persistent and environmental levels may continue to increase over time due to indirect release pathways. The scale and time frame of such an increase, and its relevance to characterising the long term environmental risk profile of these components, currently remain unknown.

Key Findings

Based on available domestic and international data, 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 perfluorohexanoate, perfluoropentanoate, and perfluorobutanoate anions. These perfluorinated anions are highly persistent and mobile and, as a result, have the potential to become globally distributed. Nevertheless, currently available data indicate that these substances are not expected to be highly bioaccumulative or toxic to aquatic organisms.

The chemicals in this group are not PBT substances according to domestic environmental hazard criteria.

Recommendations

The chemicals in this group are not prioritised for further assessment under the IMAP Framework.

However, further assessment may be necessary if information becomes available indicating that these chemicals are introduced into Australia in significant quantities, or if hazard data become available indicating adverse effects on the environment.

The Action Plan

Sufficient data are available to demonstrate a lower toxicity profile for short-chain PFCAs (containing 3, 4, and 5 perfluorinated carbons) compared with PFOA. It is therefore recommended that this assessment be included in the action plan currently contained in Appendix G of the Handbook for Notifiers (NICNAS, 2015b) as the default source of environmental data for chemicals that degrade to short-chain PFCAs containing three to five perfluorinated carbons. Any changes to the assessment outcomes under the action plan, for chemicals that degrade to short-chain PFCAs, will be considered as part of the IMAP assessment for indirect precursors of short-chain PFCAs.

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 hexanoic acid, undecafluoro- (PFHxA); and hexanoic acid, undecafluoro-, ammonium salt (ammonium PFHxA) 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 3 (H402)	Harmful to aquatic life
Chronic Aquatic	-	Not classified

The classification of the hazards posed by these chemicals has been performed based on the ecotoxicity data presented for PFHxA in this assessment. Acute data demonstrate aquatic toxicity between 1 and 100 mg/L. Chronic ecotoxicity data indicate that the chemicals in this group do not meet chronic aquatic classification criteria, as available toxicity endpoints are greater than 1 mg/L. The chemicals in this group were not classified as Chronic Category 4 ("safety net classification"), as the available evidence indicates low bioaccumulation potential for perfluorohexanoic acid in aquatic organisms and there are chronic NOEC values greater than 1 mg/L.

Insufficient data are available to classify the aquatic hazards of pentanoic acid, nonafluoro- (PFPeA); pentanoic acid, nonafluoro-, ammonium salt (ammonium PFPeA); butanoic acid, heptafluoro- (PFBA); and butanoic acid, heptafluoro-, anhydride (PFBA anhydride) according to the third edition of the GHS (UNECE, 2009). However, it is noted that these chemicals are expected to be less toxic than the C₆ homologues.

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