



Environment  
Agency



Environmental risk evaluation report:  
1,1,1,2,2,3,3-Heptafluoro-3-  
[(trifluorovinyl)oxy]propane [PPVE]  
(CAS no. 1623-05-8)

Chief Scientist's Group report

April 2023

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# Research at the Environment Agency

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This report is the result of research commissioned by the Environment Agency's Chief Scientist's Group.

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If you have any comments or questions about this report or the Environment Agency's other scientific work, please contact [research@environment-agency.gov.uk](mailto:research@environment-agency.gov.uk).

Dr Robert Bradburne  
**Chief Scientist**

# Acknowledgements

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# Executive summary

There is growing regulatory concern at international level about the emissions of per- and polyfluoroalkyl substances (PFAS) to the environment. This is due to their extreme persistence, which could lead to long-term exposure of both people and wildlife. High levels of exposure to certain PFAS has also been shown to cause harmful effects in humans and some have been declared to be 'Persistent Organic Pollutants' (POPs) under the United Nations Environment Programme (UNEP) Stockholm Convention.

The UK Government is developing an action plan to address the concerns arising from PFAS. As a contribution to this work, the Environment Agency informally reviewed several PFAS that are known to be used at two UK production facilities. The substance reviewed in this evaluation report is 1,1,1,2,2,3,3-heptafluoro-3-[(trifluorovinyl)oxy]propane or PPVE (CAS number 1623-05-8).

PPVE is a PFAS that belongs to the group of per-/polyfluorinated vinyl ethers. It is imported to the UK and used as a monomer in the manufacture of fluoropolymers at a single site. Unreacted PPVE may be present in fluoropolymers at very low concentrations, so may be released during the polymer processing stage as well as from articles at trace levels.

The Environment Agency has identified publicly available information on the regulatory status, uses, physico-chemical properties, environmental fate and (eco)toxicity of PPVE and has reviewed this information for reliability. Further information has also been sought from the UK importer. The data have then been used to conduct an environmental hazard and risk assessment. Human health hazards have only been reviewed in so far as they are relevant for the environmental assessment. Potential risks to people following environmental exposure have not been addressed.

Further information is needed to confirm whether PPVE has the potential to rapidly hydrolyse. It is not readily biodegradable, although it is expected to degrade in air. In addition, there is no information on degradation rates or half-lives available from simulation studies. PPVE is therefore currently considered to be potentially persistent or very persistent (P/vP). Screening level data indicate that bioconcentration in fish and bioaccumulation in air-breathing organisms are unlikely to be high, but there is some uncertainty in this conclusion. PPVE does not meet the criteria to be considered toxic (T). PPVE is therefore not considered to be PBT or vPvB, although it is likely to be a source of perfluoropropionic acid (PFPA) in the environment.

Draft criteria have been proposed by the EU to identify chemicals that are persistent, mobile and toxic (PMT) or very persistent and very mobile (vPvM). PPVE does not meet the draft PMT/vPvM criteria, although there is uncertainty in the data used for the mobility criterion and a reliable measurement could lead to a reassessment. PPVE transforms to PFPA in the environment, which is expected to be vPvM



On the basis of low releases and lack of significant adverse effects in the information currently available, the Environment Agency considers that the direct risk to the environment from PPVE is likely to be low.

A number of recommendations are made to the UK importer of PPVE to improve the data package to allow a more robust assessment of the environmental hazards and risks posed by PPVE. This report, along with others in this series, will be used by the Environment Agency to inform the UK Government action plan on PFAS and the PFAS Regulatory Management Options Analysis (RMOA) being conducted under the UK REACH Regulation.

# Introduction

There is growing regulatory concern at international level about the emissions of per- and polyfluoroalkyl substances (PFAS) to the environment. This is due to their extreme persistence, which could lead to long-term exposure of both people and wildlife. High levels of exposure to certain PFAS has also been shown to cause harmful effects in humans and some have been declared to be 'Persistent Organic Pollutants' (POPs) under the United Nations Environment Programme (UNEP) Stockholm Convention.

The UK Government is developing an action plan to address the concerns arising from PFAS. As a contribution to this work, the Environment Agency informally reviewed several substances that are being used at two known UK production facilities, namely AGC Chemicals Europe Ltd of Thornton Cleveleys, Lancashire and F2 Chemicals Ltd of Preston, Lancashire. Based on information provided by these UK companies, a provisional list of PFAS for further consideration was drawn up. This includes the following eight substances which were, at the time, registered at more than 1 tonne per year under the EU REACH Regulation<sup>1</sup> and subsequently also under UK REACH. Additionally a potential substitute for perfluorooctanesulfonic acid (PFOS, which is a known POP) was included that had been identified from UK surface water monitoring data. These substances chosen for further evaluation are listed below:

- Ammonium difluoro[1,1,2,2-tetrafluoro-2-(pentafluoroethoxy)ethoxy]acetate - also known as perfluoros[(2-ethoxy-2-fluoroethoxy)acetic acid], ammonium salt or EEA-NH<sub>4</sub> (CAS no. 908020-52-0)
- Trideca-1,1,1,2,2,3,3,4,4,5,5,6,6-fluorohexane - also known as 1H-perfluorohexane or 1H-PFHx (CAS no. 355-37-3)
- 3,3,4,4,5,5,6,6,6-Nonafluorohexene - also known as perfluorobutylethylene or PFBE (CAS no. 19430-93-4)
- **1,1,1,2,2,3,3-Heptafluoro-3-[(trifluorovinyl)oxy]propane - also known as perfluoro(propyl vinyl ether) or PPVE (CAS no. 1623-05-8)**
- 1,1,1,2,2,3,3,4,5,5,5-Undecafluoro-4-(trifluoromethyl)pentane - also known as perfluoroisohexane or PFiHx (CAS no. 355-04-4)
- Perflunafene - also known as perfluorodecalin or PFD (CAS no. 306-94-5)

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<sup>1</sup> Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) - see:

[https://ec.europa.eu/environment/chemicals/reach/reach\\_en.htm](https://ec.europa.eu/environment/chemicals/reach/reach_en.htm)

- Hexafluoropropene or HFP (CAS no. 116-15-4)
- Octafluoropropane - also known as perfluoropropane or PFP (CAS no. 76-19-7)

The additional substance also being considered is:

- 6:2 Chlorinated polyfluorinated ether sulfonate, 6:2 Cl-PFESA - also known as 'F-53B' (CAS no. 73606-19-6)

This report summarises the evaluation of the substance highlighted above in **bold** (i.e. PPVE) to address the following questions:

- What data are currently available, and are they sufficiently reliable to assess the environmental hazards and risks from this substance?
- Can we establish numerical exposure limits for assessing environmental impacts (e.g. for use under permitting regimes)?
- Is this substance potentially able to reach remote environments and what is its groundwater contamination potential?
- Is this substance a potential candidate for future risk management?
- What information gaps remain, relative to the registered tonnage of this substance and, if required, what is the most appropriate way of obtaining this information?

The Environment Agency has performed a literature review (Appendix A). Information on the substance's properties and uses is also provided on the European Chemicals Agency (ECHA) public dissemination website. Unless stated otherwise, the ECHA website and data provided by the UK importer, are the main source of information for this report.

The report describes the substance and its structural analogues, its analytical chemistry, manufacture and use, regulatory status and then various environmentally relevant properties. This is followed by an environmental hazard assessment, then an exposure and risk assessment. The final section summarises the findings of this review. Although the focus of this report is on environmental hazards and risks, there is a brief summary of mammalian toxicology data where available and relevant to the environmental assessment. A full consideration of hazards, exposure and risks to people is however not included. This is not a formal UK REACH evaluation.

# 1 Substance identity

## 1.1 Name and other identifiers

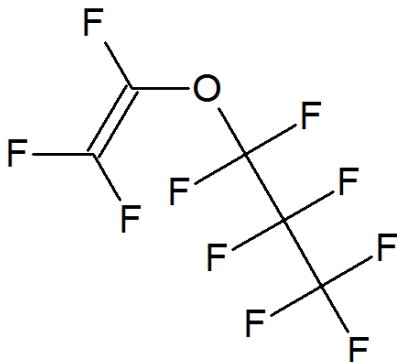
**Table 1.1 Substance identifiers**

<b>Public name</b>	Perfluoroethyl vinyl ether [PPVE]*
<b>IUPAC name</b>	1,1,1,2,2,3,3-Heptafluoro-3-[(trifluorovinyl)oxy]propane
<b>CAS name</b>	Heptafluoropropyl trifluorovinyl ether
<b>EC number</b>	216-600-2
<b>CAS number</b>	1623-05-8
<b>Index number in Annex VI of the CLP Regulation</b>	-
<b>Molecular formula</b>	C <sub>5</sub> F <sub>10</sub> O
<b>Molecular weight</b>	266.04
<b>SMILES code(s)</b>	C(=C(F)F)(OC(C(C(F)(F)F)(F)F)(F)F)F
<b>Synonyms</b>	Decafluoro-3-oxa-1-hexene; Decafluoro vinyl n-propyl ether; 1,1,1,2,2,3,3-Heptafluoro-3-(1,2,2-trifluorovinyl)oxy]propane; 1,1,1,2,2,3,3-Heptafluoro-3-(1,2,2-trifluoro-ethenoxy)-propane; 1,1,2,2,3,3,3-Heptafluoropropyl 1,2,2-trifluorovinyl ether; Perfluoropropoxyethylene; Perfluoropropyl perfluorovinyl ether; Propane, 1,1,1,2,2,3,3-heptafluoro-3-[(trifluoroethenyl)oxy]-; Propane, 1,1,1,2,2,3,3-heptafluoro-3-[(1,2,2-trifluoroethenyl)oxy]-; Trifluoro(heptafluoro-1-propoxy)ethene; Trifluoro(heptafluoro-1-propoxy)ethylene
<b>Type of substance</b>	Mono-constituent

Note: \* The substance is referred to using its abbreviated form [PPVE] for the purposes of this report.

SMILES - Simplified Molecular Input Line Entry System

**Figure 1.1 Structural formula of PPVE**



Further details of the composition (e.g. purity, impurities, etc.) of PPVE are confidential.

## 1.2 Structurally related substances

PPVE is a fully fluorinated vinyl ether. Structurally related substances were identified through the US Environmental Protection Agency (US EPA) CompTox Dashboard (US EPA, 2020a). The dashboard identified related substances in its records using connectivity (first layer 'InChI'), mixture components and isotopic isomers, and the Tanimoto coefficient (>0.8). InChI is the IUPAC international identifier and uses a software model to assign an identifier to a molecule which describes structure.

Only a handful of potential analogues were identified (Appendix B) of which only the following two are registered under EU REACH:

- The non-fluorinated analogue 1-(vinyl)propane (CAS no. 764-47-6) is registered under the EU REACH Regulation for intermediate use only. There are no property data on the ECHA database (ECHA, 2021a).
- Of the closest analogues, only perfluoro(ethyl vinyl ether) (PEVE) (CAS no. 10493-43-3) has a registration dossier on the ECHA database (ECHA, 2021b). The Environment Agency has therefore chosen to focus on PEVE for weight of evidence judgments for the purposes of this evaluation. The saturated alkyl chain of PEVE is shorter by one carbon atom compared to PPVE, so PEVE has a lower molecular weight and different physical state under environmental conditions (it is a gas). Information on PEVE is presented in Table 1.2.

The ether group could potentially act as a point for chemical attack within the molecule, although ethers are generally of low chemical reactivity. In addition, fluorine atoms are

highly electronegative and so will withdraw charge from the main body of the molecule, which may increase stability compared with other alkyl ethers.

**Table 1.2 Substance identifiers for PEVE**

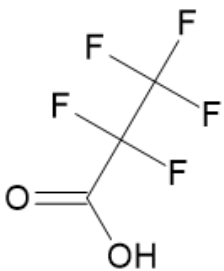
<b>Name</b>	Perfluoro(ethyl vinyl ether)
<b>IUPAC name</b>	1,1,2-Trifluoro-2-(1,1,2,2,2-pentafluoroethoxy)ethene
<b>CAS number</b>	10493-43-3
<b>EC number</b>	234-018-7
<b>Structural formula</b>	
<b>Molecular formula</b>	C <sub>4</sub> F <sub>8</sub> O
<b>Molecular weight</b>	216.03 g/mol
<b>SMILES code</b>	C(=C(F)F)(OC(C(F)(F)F)(F)F)F
<b>Synonyms</b>	Octafluoro-2-oxa-1-pentene; Trifluoro(pentafluoroethoxy)ethylene; 1,1,2-Trifluoro-2-(pentafluoroethoxy)ethylene; Pentafluoroethyl trifluorovinyl ether
<b>Comment, relationship to PPVE</b>	Belongs to the per-/polyfluorinated vinyl ether group, with one less CF <sub>2</sub> group in the alkyl chain than PPVE (and hence a lower molecular weight)
<b>Source</b>	ECHA (2020a) US EPA (2020c)

### 1.3 Transformation products

According to the EU REACH registrations, PPVE can transform in the environment to perfluoropropionic acid (PFPA) (CAS no. 422-64-0) (see Section 6.1.1). This is considered to be the ultimate transformation product (a so-called “arrowhead”) as it is likely to be highly persistent. It has a registration dossier on the ECHA database (ECHA, 2021c). Information on PFPA is presented in Table 1.3. It belongs to a homologous series of

perfluorocarboxylic acids, including perfluorohexanoic acid (PFHxA) (CAS no. 307-24-4) (ECHA, 2021d). The Environment Agency has not performed a detailed search for information on this substance for the purposes of this assessment.

**Table 1.3 Substance identifiers for PFPA**

<b>Name</b>	Perfluoropropionic acid
<b>IUPAC name</b>	2,2,3,3,3-Pentafluoropropanoic acid
<b>CAS number</b>	422-64-0
<b>EC number</b>	207-021-6
<b>Structural formula</b>	
<b>Molecular formula</b>	C <sub>3</sub> HF <sub>5</sub> O <sub>2</sub>
<b>Molecular weight</b>	164.03 g/mol
<b>SMILES code</b>	C(=O)(C(C(F)(F)F)(F)F)O
<b>Synonyms</b>	Pentafluoropropanoic acid Perfluoropropionate PFPA
<b>Source</b>	ECHA (2021c)



## 2 Analytical chemistry

### 2.1 Regulatory and academic methods

The Chemical Safety Report (CSR) submitted in the EU REACH registration contains a reference to a purge and trap gas chromatography/mass spectrometry (GC/MS) technique that was used for water solubility assessment. A further confidential analytical method is discussed but no further details given (ECHA, 2020b).

The Environment Agency searched the academic literature for analytical methods for the detection of PPVE and associated transformation products in the following environmental matrices: water, fresh and marine; soil; sediment; sludge; and air. No analytical methods for the detection of PPVE in environmental compartments were located.

Analytical monitoring of PPVE in environmental matrices has not been published as part of national or international programmes. PPVE is listed in the following databases, but no associated analytical methods are detailed (non-exhaustive list):

- PFASTRIER list (NORMAN network 2020).
- PFAS/US EPA: List of 75 Test Samples (Set 1) - this corresponds to substances submitted for the initial testing screens conducted by US EPA researchers in collaboration with researchers at the National Toxicology Program (US EPA, 2021g).
- ToxCast Chemical inventory (US EPA 2020a).

The Environment Agency considers that the description of a robust analytical method will typically include the following details:

- Instruments and consumables including chromatographic column, temperature, mobile phase composition, flow rates, gradient or isocratic separation and the detector optimisation and configuration.
- Certified reference standards, calibration range and sensitivity, limit of detection, limit of quantification, column recoveries, stability and reproducibility.
- The use of procedural blanks and control samples in both sample preparation and analysis.
- Sample preparation including clean-up consumables, concentration techniques and use of internal standards (plus justification for choice) for validation, recoveries, etc.
- Identification and discussion of technical limitations.

### 3 Import, manufacture and uses

Although the UK left the EU at the end of January 2020, European chemicals legislation in place by December 2020 has been retained and transposed in to UK law. ECHA, who administer EU REACH as well as the EU Classification, Labelling and Packaging (CLP) Regulation ((EC) No. 1272/2008), is therefore still a relevant source of information about industrial chemicals on the UK market at the time of writing.

PPVE is registered under the EU REACH Regulation by 10 Registrants at an aggregated supply level 100 to 1 000 tonnes/year. AGC Chemicals Europe Ltd ([www.agcce.com](http://www.agcce.com)) was one of the co-registrant before the UK left the EU. They have a manufacturing site at Thornton Cleveleys near Blackpool, Lancashire and import PPVE into the UK from Japan. Personal communication with the company indicates that their supply is significantly lower than the EU aggregated level.

AGC Chemicals Europe Ltd has an environmental permit (ref: EPR/BU5453IY) under the Environmental Permitting (England and Wales) Regulations 2016. It produces two main product streams:

- polytetrafluoroethylene (PTFE) with a capacity up to 4 000 tonnes/year
- ethylene-tetrafluoroethylene (ETFE) with a capacity up to 2 000 tonnes/year

PPVE is used in the manufacture of fluoropolymer resins as a co-monomer (McKeen, 2014). PPVE is used as a trace co-monomer to manufacture PTFE grades which give slightly different properties to homopolymer PTFE material. AGC Chemicals Europe Ltd has informed the Environment Agency that their product is used for wire coatings, cables and tubing in the semi-conductor industry and cable insulation in the automotive and aerospace industry.

An overview of uses provided in the EU REACH registration information on the ECHA website is presented in Table 3.1.

**Table 3.1 Overview of uses**

Life cycle stage	Use(s)
<b>Manufacture</b>	<p><b>Manufacture of substance</b>                      ERC1: Manufacturing</p> <p>PROC 3: Manufacture or formulation in the chemical industry in closed batch processes with occasional controlled exposure or processes with equivalent containment conditions</p> <p>PROC 8b: Transfer of substance or mixture (charging and discharging) at dedicated facilities</p> <p>PROC 9: Transfer of substance or mixture into small containers (dedicated filling line, including weighing)</p> <p>PROC 15: Use as laboratory reagent</p> <p>PROC 28: Manual maintenance (cleaning and repair) of machinery</p>
<b>Formulation</b>	<p><b>Formulation</b>                      ERC2: Formulation into mixture</p> <p>PROC 1: Chemical production or refinery in closed process without likelihood of exposure or processes with equivalent containment conditions</p> <p>PROC 8a: Transfer of substance or mixture (charging and discharging) at non-dedicated facilities</p> <p>PROC 8b: Transfer of substance or mixture (charging and discharging) at dedicated facilities</p> <p>PROC 15: Use as laboratory reagent</p>
<b>Uses at industrial sites</b>	<p><b>Use as intermediate</b>                      ERC6a: Use of intermediate                      ERC6b: Use of reactive processing aid at industrial site (no inclusion into or onto article)</p> <p>PROC 8a: Transfer of substance or mixture (charging and discharging) at non-dedicated facilities</p> <p>PROC 8b: Transfer of substance or mixture (charging and discharging) at dedicated facilities</p> <p>PROC 15: Use as laboratory reagent</p> <p>PROC 0: Other: Intermediate use</p>

Life cycle stage	Use(s)
	<p><b>Polymerisation at industrial site</b></p> <p>ERC6c: Use of monomer in polymerisation processes at industrial site (inclusion or not into/onto article)</p> <p>PROC 1: Chemical production or refinery in closed process without likelihood of exposure or processes with equivalent containment conditions</p> <p>PROC 3: Manufacture or formulation in the chemical industry in closed batch processes with occasional controlled exposure or processes with equivalent containment conditions</p> <p>PROC 8b: Transfer of substance or mixture (charging and discharging) at dedicated facilities</p> <p>PROC 9: Transfer of substance or mixture into small containers (dedicated filling line, including weighing)</p> <p>PROC 15: Use as laboratory reagent</p>
<p><b>Article service life</b></p>	<p>None identified in registration dossier</p>

Note: PROC codes are Process Codes, descriptors for the process types

# 4 Summary of relevant regulatory activities

## 4.1 Europe

### 4.1.1 European Chemicals Agency (ECHA)

The Public Activities Co-ordination Tool (PACT) (<https://echa.europa.eu/pact>) provides an overview of the substance-specific activities that EU regulatory authorities are working on under the EU REACH and CLP Regulations. PPVE is not currently included on PACT, and neither is it listed on the Community Rolling Action Plan (CoRAP) (<https://echa.europa.eu/information-on-chemicals/evaluation/community-rolling-action-plan/corap-table>).

Between May and July 2020, the national authorities of Germany, the Netherlands, Norway, Sweden and Denmark invited interested parties to send in evidence and information on the use of PFAS in preparation for a joint EU REACH restriction proposal. The current scope of the work is wide and includes all substances that contain at least one aliphatic -CF<sub>2</sub>- or -CF<sub>3</sub> element (see <https://www.rivm.nl/en/pfas/pfas-restriction-proposal> and ECHA Registry of Restriction Intentions: <https://echa.europa.eu/registry-of-restriction-intentions/-/dislist/details/0b0236e18663449b>, both accessed October 2021). PPVE is therefore within scope of this initiative.

### 4.1.2 European Food Safety Agency (EFSA)

EFSA provides scientific advice on safety of food additives, enzymes, flavourings, processing aids and other substances intentionally added to food; safety of food packing and other food contact materials.

A search of the EFSA website (<http://www.efsa.europa.eu/>) did not identify PPVE as being evaluated or noted in any published scientific opinions.

PPVE is listed in Annex I of EC Regulation 10/2011 (EC, 2011) as an authorised monomer in the production of food contact material with a specific migration limit of 0.05 mg/kg.

### 4.1.3 Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR)

OSPAR is a mechanism by which 15 national governments and the EU co-operate to protect marine resources. Much of OSPAR's work on chemicals is now being addressed by REACH activities.

PPVE is not on the OSPAR List of Substances of Possible Concern <https://www.ospar.org/work-areas/hasec/hazardous-substances/possible-concern>

(accessed July 2020), nor on the list of Chemicals for Priority Action adopted in 2002 <https://www.ospar.org/work-areas/hasec/hazardous-substances/priority-action> (accessed July 2020).

## 4.2 Regulatory activity outside Europe

### 4.2.1 United States

The US EPA is planning to carry out tiered toxicity and toxicokinetic testing for a range of PFAS in the near future (Patlewicz *et al.*, 2019). PPVE is listed in the Patlewicz *et al.* study.

PPVE is not listed as one of the substances undergoing risk evaluation as part of US EPA's existing chemical initiative under the Toxic Substances Control Act (TSCA) to determine whether they present an unreasonable risk to public health or the environment under the conditions of use (US EPA, n.d. a; US EPA, n.d. b).

### 4.2.2 Canada

A search did not identify PPVE as being under assessment under the Prohibition of Certain Toxic Substances Regulations, 2012 (<https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/substances-list/toxic.html>), accessed July 2020).

### 4.2.3 Australia

A search did not identify PPVE as being under assessment under the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) (<https://www.nicnas.gov.au/chemical-information/imap-assessments/imap-assessments>), accessed July 2020).

### 4.2.4 New Zealand

A search did not identify PPVE as being under assessment under the Hazardous Substances and New Organisms Act 1996 (<https://www.epa.govt.nz/industry-areas/hazardous-substances/>, accessed July 2020; <https://www.epa.govt.nz/industry-areas/hazardous-substances/chemical-reassessment-programme/screened-chemicals-list/>, accessed July 2020).

### 4.2.5 Japan

Industrial chemicals are managed under the Chemical Substances Control Law (CSCL), most recently amended in 2009. Under the Act there are 3 lists:

- Class I Specified Chemicals - 28 substances (persistent, bioaccumulative, toxic) ([https://www.nite.go.jp/chem/jcheck/list6.action?category=211&request\\_locale=en](https://www.nite.go.jp/chem/jcheck/list6.action?category=211&request_locale=en))
- Class II Specified Chemicals - 23 substances (toxic and high risk) ([https://www.nite.go.jp/chem/jcheck/list6.action?category=212&request\\_locale=en](https://www.nite.go.jp/chem/jcheck/list6.action?category=212&request_locale=en))
- Priority Assessment Chemical Substance (PACS), currently 226 substances ([https://www.nite.go.jp/chem/jcheck/list7.action?category=230&request\\_locale=en](https://www.nite.go.jp/chem/jcheck/list7.action?category=230&request_locale=en))

PPVE is not on any of the above lists.

## 4.3 Other international agreements

### 4.3.1 United Nations Stockholm Convention on Persistent Organic Pollutants (POPs)

PPVE is not identified as a POP, and is not currently under evaluation

(<http://chm.pops.int/TheConvention/ThePOPs/AllPOPs/tabid/2509/Default.aspx>, accessed July 2020).

### 4.3.2 Greenhouse gases

PPVE is not a gas at normal temperatures and pressures, so is not subject to the EU F-Gas Regulation (EU) No. 517/2014 ([https://ec.europa.eu/clima/policies/f-gas/legislation\\_en#](https://ec.europa.eu/clima/policies/f-gas/legislation_en#)). It is however highly volatile (see Section 5.1).

## 5 Physicochemical properties

This evaluation focusses on vapour pressure, water solubility and n-octanol-water partition coefficient, because they are the key physico-chemical end points for the environmental assessment of most organic chemicals. Surface tension and dissociation constant are also considered. The available information is discussed in this section, and a conclusion drawn about which value the Environment Agency considers most suitable for the further evaluation of this substance.

The source of this information is the publicly available EU REACH registration database (ECHA, 2021e; accessed February 2021) unless otherwise indicated. The reliability scores provided in the full registration for individual studies are cited. These scores have presumably been generated in accordance with the ECHA R.4. Guidance Document (ECHA, 2011). An independent evaluation has not been possible since original study reports were not available (and have not been requested at this stage), and the EU public REACH registration dossiers generally lack sufficient supporting information. The Environment Agency is therefore not currently able to assign its own reliability scores (except in the case of data presented in academic journals or obtained using quantitative structure-activity relationship (QSAR) models).

Where an endpoint value is missing from the EU REACH registration dossier, or an initial review raised questions around the validity of an experimentally derived value, the assessment has been supplemented with information from analogues (see Section 1, and Appendix B) and publicly available *in silico* QSAR models. EU REACH registration data for the analogues are taken at face value, although preference is given to regulatory reviews (if available). QSAR models are generally considered to be a screening-level tool and measured values are preferable, provided that they are sufficiently reliable. Further information is provided in Appendix C.

Where a value for an endpoint was not presented in the registration dossier, or where questions arose around the validity of an experimentally derived endpoint, openly available QSAR model data were referenced. *In silico* models are screening-level tools and were not used if acceptable measured values were available in the registration dossier. One main database was used to source *in silico* data for this evaluation when required. This was the United States Environmental Protection Agency (US EPA) CompTox Dashboard (<https://comptox.epa.gov/dashboard>). This database integrates diverse types of relevant domain data through a cheminformatics platform and is built upon a database of curated substances properties linked to chemical structures (Williams *et al.*, 2017). The US EPA CompTox Dashboard allows access to data produced from the QSAR models, these data have been used to supplement information where limited data were presented in the EU REACH registration (data from other open access models are available from the dashboard). In addition, where the EU REACH registration had generated QSAR values for endpoints that were not considered to be feasible the Environment Agency has used EPISuite™v4.1 to perform further predictions. Additional restraint in judgement of reliability



should be applied to the values generated using *in silico* tools because this substance is a salt conjugate. EPISuite™v4.1 inputs rely on SMILES codes that cannot be input as charged substances or fragments.

An overview of physico-chemical data provided in the EU REACH registration or generated by the Environment Agency is presented in Table 5.1.

## 5.1 Vapour pressure

### 5.1.1 Measured data

A key experimental study and two supporting studies were presented in the EU REACH registration dossier.

The key experimental study (Unnamed study report, 2015; ECHA, 2021e) was GLP compliant and carried out according to OECD Test Guideline (TG) 104. Vapour pressure was measured at 6 temperatures using the static method to generate a regression curve. This vapour pressure was 55 kPa at 20 °C and 67 kPa at 25 °C. The EU REACH registration assessed the data reliability as Klimisch 1 (reliable without restrictions).

The first supporting study (Unnamed study report, 1985; ECHA, 2020b) did not contain detail relating to GLP compliance, guideline used, testing lab or substance composition, and was therefore assigned a Klimisch score of 4 (not assignable) in the EU REACH registration. Vapour pressure was measured at 5 different temperatures (21.6 to 91.8 °C) using the static method, and the reported vapour pressure was 51.7 kPa at 20 °C.

The second supporting study (Unnamed study report, 2007; ECHA, 2020b) did not contain information relating to the test substance composition and was not GLP compliant. Vapour pressures were measured at 8 temperatures (0.01 to 69.99 °C) using a Ruska high temperature differential pressure null detector. The EU REACH registration assigned a Klimisch score of 2 (reliable with restrictions). The reported vapour pressure was 51.8 kPa at 20 °C.

The Environment Agency notes the consistency in results from the three studies.

### 5.1.2 Predicted data

No *in silico* predictive data were presented in the EU REACH registration for this endpoint.

The Environment Agency consulted the Chemspider (RSC, 2020), and US EPA CompTox (US EPA, 2020a) databases. The US EPA CompTox dashboard contained data generated from ACD/Labs and OPERA software. These data are presented in Table 5.2 (the Environment Agency has converted the values from mmHg to kPa).

**Table 5.1 Summary of physico-chemical properties**

Property	Value(s)	Reliability Klimisch score	Reference
Physical state at 20 °C and 101.3 kPa	Colourless liquid	Registrant: 1	Registration dossier
Melting / freezing point	< -80 °C (method in accordance with OECD TG 102, GLP compliant, unnamed study)	Registrant: 1 (key study)	Registration dossier
Boiling point	47.3 °C (extrapolated from measurements made using differential scanning calorimetry, OECD TG 103, GLP compliant, unnamed study)	Registrant: 1 (key study)	Registration dossier
Relative density	1.56 g/cm <sup>3</sup> at 20 °C (Anton Paar density measuring cell, non-GLP compliant, unnamed study)	Registrant: 2 (key study)	Registration dossier
Vapour pressure	55 kPa at 20 °C and 67 kPa at 25 °C (extrapolated from measurements using the static method, OECD TG 104, GLP compliant, unnamed study)	Registrant: 1 (key study)	Registration dossier
Surface tension	Data waiver	-	Registration dossier
Water solubility	1.8 mg/L at 22.3 °C (OPPTS 830.7840, shake flask method, GLP compliant, unnamed study)	Registrant: 1 (key study)	Registration dossier
n-Octanol/water partition coefficient (log K <sub>ow</sub> )	4.0 at 21.9 °C (OPPTS 830.7550, OECD TG 107, shake flask method, GLP compliant, unnamed study)	Registrant: 1 (key study)	Registration dossier
Particle size distribution	Not relevant – the substance is a liquid at room temperature and atmospheric pressure	-	Registration dossier

Property	Value(s)	Reliability Klimisch score	Reference
Stability in organic solvents and identity of relevant degradation products	Data waiver	-	Registration dossier
Dissociation constant	Data waiver	-	Registration dossier

**Table 5.2 Predicted vapour pressures for PPVE**

Source	Prediction method	Vapour pressure at 25 °C
<b>ACD/Labs</b>	Not available	38.5 kPa [289 mmHg]
<b>EPISuite™ MPBPVP v 1.42</b>	Mean of Antoine and Grain Methods BP = 23.14 °C MP = -112.4 °C	108.1 kPa [811 mmHg]
<b>OPERA</b>	Global applicability domain: Inside Local applicability domain index: 0.402 Confidence level: 0.577	28.4 kPa [213 mmHg]

*In silico* predicted values should always be treated with caution where substances in the training set and external test set are not visible.

- This information was not available for the ACD/labs models and therefore no assessment of the applicability can be performed.
- Guidance provided with the MPBPWIN model indicates that the relationship between the experimental and predicted values for a test set of 1 642 compounds was good, with an R<sup>2</sup> of 0.949, standard deviation of 0.59 and an average deviation of 0.32. The training set contained several perfluorocarbons (see Appendix C) although no close structural analogues of PPVE were identified. The Environment Agency considers it unlikely that the predicted value for PPVE falls within the applicability domain of the model.
- For the OPERA model, although PPVE is considered inside the global applicability domain and has a local applicability domain index of 0.4 to 0.6, there are no close structural analogues of PPVE included in the training and external test sets. The Environment Agency considers that the predicted value for PPVE is therefore likely to be inaccurate.

### 5.1.3 Data from structural analogues

Given the consistency in the three reported experimental values for PPVE, information from structural analogues was not considered.

### 5.1.4 Additional sources

No relevant references were identified in the literature search.

### 5.1.5 Recommended value

The EU REACH registration dossier (ECHA, 2021e) indicates that the vapour pressure is in the range 51.7 to 55.0 kPa at 20 °C, with a value of 55.0 kPa from the key study presented in the EU REACH registration. The range of *in silico* predicted values (28.4 to 108.1 kPa at 25 °C; US EPA, 2020a and RSC, 2020) is broadly consistent.

Although the original study reports are not available for an independent review, the Environment Agency considers that a vapour pressure of **55.0 kPa at 20 °C** is sufficiently reliable for use in further assessment.

## 5.2 Surface tension

### 5.2.1 Measured data

The EU REACH registration dossier contains a data waiver, indicating that the substance structure lacks the groups necessary for surface activity, and so surface activity is not an expected property.

### 5.2.2 Predicted data

No *in silico* predictive data were presented in the EU REACH registration for this endpoint.

The Environment Agency consulted the ChemSpider (RSC, 2020) and US EPA CompTox (US EPA, 2020a) databases. The US EPA CompTox dashboard contained data generated from ACD/Labs, suggesting a surface tension of 12.5 mN/m for PPVE. Based on evidence for other PFAS, the Environment Agency believes that this represents the surface tension of the substance itself, rather than an aqueous solution. The QSARs have therefore not been considered further.

### 5.2.3 Data from structural analogues

No further data providing information on surface activity was available for the structural analogue PEVE. However, the effect of the surface activity on water from perfluorocarbons which are structurally related to PPVE are discussed in Section 5.2.4.

## 5.2.4 Additional sources

There are structural similarities between PPVE and perfluoropentane. Therefore, information provided by Chernysheva and Skliar (2014) provides an indication of the potential effect of the surface tension of PPVE in aqueous solutions.

Chernysheva and Skliar (2014) reported a small decrease in the surface tension of deionised water in the presence of perfluorocarbon vapours. The surface tension of the water reduced from 72 mN/M to 64.6 mN/M in the presence of perfluoropentane and 66.7 mN/M in the presence of perfluorohexane at 20 °C. The study suggests that there is some potential for the formation of a separate perfluorocarbon layer at the water-air interface in aqueous solution.

## 5.2.5 Recommended value

Surface tension in water is important because it affects the measurement and interpretation of other physico-chemical properties such as water solubility and partitioning coefficients.

The EU REACH registration provides a waiver for the endpoint stating that PPVE will not be surface active on structural grounds. The Environment Agency notes that other than an oxygen atom, it does not have any hydrophilic structural groups that can form hydrogen or Van der Waals bonds in water, which suggests that it is unlikely to be significantly surface active in aqueous solutions.

Evidence from Chernysheva and Skliar (2014) for perfluorocarbons of a similar molecular weight suggests that there is some potential for the formation of a separate PPVE layer at the water-air interface in aqueous solution.

## 5.3 Water solubility

### 5.3.1 Measured data

One key experimental study is presented in the EU REACH registration dossier (Unnamed study report, 2015; ECHA, 2020b). The study was carried out according to the US EPA OPPTS 830.7840 guideline (a flask method) and was GLP compliant. The EU REACH registration has assigned a Klimisch score of 1 (reliable without restriction). In the study, 3 vials were prepared for each time point (5, 6 and 7 days) and incubated at an average temperature of 22.3 °C (21 to 24.8 °C). This range implies a 20-30% deviation from the guideline temperature. Each vial was centrifuged before the start of the experiment for at least 24 hours, and again just before collection of the supernatant samples after equilibration for 5, 6 or 7 days. The PPVE concentration was then determined in each vial using purge and trap GC/MS to allow the determination of an average water solubility. This was reported as 1.7 mg/L on day 5, 1.9 mg/L on day 6 and 1.8 mg/L on day 7, with an overall average of 1.8 mg/L.

The EU REACH registration considers that PPVE is slightly soluble (0.1 to 100 mg/L) in water.

The Environment Agency notes that although the EU REACH registration dossier does not discuss the potential for evaporative losses or describe whether the supernatant was clear, there was good consistency in the reported measurements (<15% variation).

### **5.3.2 Predicted data**

No *in silico* predictive data were presented in the EU REACH registration for this endpoint.

The Environment Agency consulted the ChemSpider (RSC, 2020) and US EPA CompTox (US EPA, 2020a) databases for the *in silico* predicted water solubility of PPVE. Both databases presented data generated in EPISuite™, with the US EPA CompTox dashboard also containing data from OPERA modelling software. The data are presented in Table 5.3 (the Environment Agency converted the units from mol/L to mg/L using a molecular weight of 266.04 g/mol).

**Table 5.3 Predicted water solubility of PPVE**

Source	Details	Water solubility
EPISuite™ Water solubility estimate from log K <sub>ow</sub> (WSKOW v1.41)	log K <sub>ow</sub> used: 3.35 (estimated) no melting point equation used	26.6 mg/L at 25 °C
EPISuite™ Water solubility estimate from fragments (v1.01 est.)	-	61.8 mg/L
OPERA	Predicted value: 5.82 x 10 <sup>-4</sup> mol/L Global applicability domain: inside Local Applicability domain index: 0.358 Confidence Interval: 0.479	155 mg/L

*In silico* predicted values should always be treated with caution where substances in the training set and external test set are not visible.

- Guidance provided with the WSKOWWIN model indicates that the relationship between the experimental and predicted vapour pressure values for a test set of 1 450 compounds was good, with an R<sup>2</sup> of 0.97, standard deviation of 0.409 and an average deviation of 0.313. It is not known whether the training set contained structurally similar substances of PPVE so care should be taken in the interpretation of these data.
- For the OPERA model, no close structural analogues of PPVE were included in the training and external test sets. The model output states that PPVE is inside the global applicability domain but it has a local applicability domain index of <0.4 and therefore the prediction is unlikely to be accurate.

### 5.3.3 Data from structural analogues

Given the consistency in the measurements reported in the available water study for PPVE, information from structural analogues was not considered.

### 5.3.4 Additional sources

According to Chernysheva and Skliar (2014), perfluorocarbons such as perfluorohexane form colloids in water, which may involve “liquid droplets, vapour bubbles or a combination of both phases simultaneously”.

### 5.3.5 Recommended value

A GLP-compliant study performed according to a recognised method for measuring water solubility is available, reporting a water solubility of 1.8 mg/L at 22.3 °C (ECHA, 2021e). The EU REACH registration considers the data to be fully reliable.

In the aquatic toxicity studies, saturated test solutions were prepared with arithmetic and geometric mean measured concentrations ranging from 0.458 to 0.622 mg/L (see Section 7). The initial concentrations may have been higher but there is no information to confirm this.

*In silico* predictions for the water solubility of PPVE were between 26.6 and 155 mg/L (US EPA, 2020a and RSC, 2020). The reliability of these predictions is uncertain, and the methods appear to over-estimate the measured solubility by at least a factor of 15.

The Environment Agency notes that the substance is likely to partition fairly easily from water to air (see Section 5.1), so controls to limit losses due to volatility may be required during water solubility measurements. Perfluorocarbon analogues form colloids in water and it is not known if the same could occur for PPVE. Both factors may complicate the measurement of aqueous solubility for this type of substance, but it is not known how they were taken into account in the key study. In addition, the EU REACH registration considers that the substance is subject to hydrolysis, but does not appear to have considered the implications for the interpretation of the water solubility measurement. The Environment Agency considers that further justification is required to substantiate the level of hydrolysis assumed (see Section 6.1.1).

Although the original study report is not available for an independent review, the Environment Agency considers that the measured water solubility of **1.8 mg/L at 22.3 °C** for PPVE is likely to be sufficiently reliable for use in further assessment. The Environment Agency recommends that the robust study summary for this end point is updated to confirm whether the analysis took steps to minimise colloid formation and volatilisation. The influence of hydrolysis also needs to be considered if this is thought to be important.

## 5.4 n-Octanol/water partition co-efficient (log K<sub>ow</sub>)

### 5.4.1 Measured data

One key experimental study (Unnamed study report, 2015; ECHA, 2021e) is presented in the EU REACH registration dossier. The study was conducted according to OPPTS 830.7550 (US EPA, 1996), equivalent to the OECD TG 107 (OECD, 1995) and was GLP compliant. The EU REACH registration has assigned a Klimisch score of 1 (reliable without restriction). The nominal concentration of PPVE (purity 98.5%) dissolved in n-octanol is not noted in the registration dossier. Flasks were prepared in duplicate at 3 n-octanol (containing PPVE):water ratios (1:1, 1:2 and 2:1). The flasks were nearly full to minimise evaporative losses. They were sealed and inverted 100 times for 5 minutes and then centrifuged at 1 500 rpm to facilitate separation before samples were left overnight. Two aliquots were taken from each phase, diluted and analysed using GC/MS. "Visibly clear separate layers" were noted. The log K<sub>ow</sub> was calculated for each ratio (1:1, 1:2 and 2:1) as 3.9, 4.0 and 4.0, respectively. Concentrations of PPVE in the water phases ranged between 118 and 171 ng/L. A log K<sub>ow</sub> of 4.0±0.05 (1.3% RSD) was determined at 21.9 °C.



The method uncertainty was calculated to be  $\pm 6.58\%$ , however no details of how this was calculated could be located in the registration dossier.

#### 5.4.2 Predicted data

No *in silico* predictive data were presented in the EU REACH registration for this endpoint.

The Environment Agency consulted the ChemSpider (RSC, 2020), and US EPA CompTox (US EPA, 2020a) databases. Both databases presented data generated in EPISuite™ and ACD/Labs, with the US EPA CompTox dashboard also containing data from OPERA and ACD/Labs consensus modelling software. The data are presented in Table 5.4.

**Table 5.4 Predicted log Kow values for PPVE**

Source	Details	log Kow
ACD/Labs	ACD/LogP	5.45
	ACD/LogD (pH 5.5)	3.78
EPISuite™	KOWWIN v 1.67 estimate	3.35
OPERA	Global applicability domain: Inside Local Applicability domain index: 0.386 Confidence Interval 0.406	2.8

*In silico* predicted values should always be treated with caution where substances in the training set and external test set are not visible.

- For the ACD/labs model this information was not available. Therefore no assessment of the applicability can be performed.
- Guidance provided with the KOWWIN model indicates that the relationship between the experimental and predicted values for a validation set of 10 331 compounds was good, with an  $R^2$  of 0.94 and standard deviation of 0.47. The training set contained several perfluorocarbons (see Appendix C) and it is likely that the predicted value for PPVE falls within the applicability domain of the model.
- For the OPERA model, no close structural analogues of PPVE were included in the training and external test sets. The model output states that PPVE is inside the global applicability domain but has a local applicability domain index of  $<0.4$  and therefore the prediction is unlikely to be accurate.

#### 5.4.3 Data from structural analogues

Given the consistency in the reported experimental values for PPVE, information from structural analogues was not considered.

#### 5.4.4 Additional sources

No relevant references were identified in the literature search.

#### 5.4.5 Recommended value

The key value in the EU REACH registration is a modern shake-flask test that determined the log  $K_{OW}$  to be 4.0 at 25 °C (ECHA, 2021e). The study was GLP compliant, and included measures to minimise volatile losses and was considered to be “fully reliable” in the EU REACH registration.

The Environment Agency notes that according to Chernysheva and Skliar (2014), perfluorocarbons can form colloids in water, which may complicate the measurement of log  $K_{OW}$ . However “visibly clear separate layers” were reported, so the Environment Agency considers that this was not a major issue (if it occurred), although microscopic investigation would have been helpful. In addition, the EU REACH registration considers that the substance is subject to hydrolysis, but does not appear to have considered the implications for the interpretation of the log  $K_{OW}$  measurement. The Environment Agency considers that further justification is required to substantiate the level of hydrolysis assumed (see Section 6.1.1).

*In silico* predictions for the log  $K_{OW}$  of PPVE were between 2.8 and 5.45 (US EPA, 2020a and RSC, 2020), although the reliability of these values is unknown. None of the methods provide a particularly close match to the reported value.

Although the original study report is not available for an independent review, the Environment Agency considers that the measured **log  $K_{OW}$  of 4.0 at 25 °C** is likely to be sufficiently reliable for use in further assessment. The influence of hydrolysis also needs to be considered if this is thought to be important.

### 5.5 n-Octanol/air partition coefficient (log $K_{OA}$ )

The log  $K_{OA}$  is a non-standard endpoint under REACH used to predict the partitioning behaviour of organic compounds between air and environmental matrices such as soil, vegetation, and aerosol particles (Meylan and Howard, 2005). Methods for measurement and calculation of the value are discussed in Environment Agency (2009).

#### 5.5.1 Measured data

No experimental log  $K_{OA}$  values were presented in the EU REACH registration (ECHA, 2020b).

#### 5.5.2 Predicted data

A calculated log  $K_{OA}$  of 0.46 is cited in the EU REACH registration dossier. There is no indication of how the value has been calculated.

The Environment Agency consulted the Chemspider (RSC, 2020), and US EPA CompTox (US EPA, 2020a) databases. The US EPA CompTox dashboard contained an estimated log  $K_{OA}$  value for PPVE of 1.96 from OPERA software and the Chemspider database

included a value of 0.797 generated using EPISuite™ (from a log K<sub>OW</sub> of 3.35 and air-water partitioning coefficient (log K<sub>AW</sub>) of 2.553).

The Environment Agency also used KOAWIN v1.10 model within EPIWIN (v 4.11) to predict a log K<sub>OA</sub> of 2.168, using a log K<sub>OW</sub> of 4 and log K<sub>AW</sub> of 1.832. These data are presented in Table 5.5.

In addition the Environment Agency also determined the log K<sub>OA</sub> as 0.48 from the Henry's Law constant (HLC) and log K<sub>OW</sub> (Table 5.5).

*In silico* predicted values should always be treated with caution where substances in the training set and external test set are not visible.

- Guidance provided with the KOAWIN model indicates that the relationship between the experimental and predicted values for a validation set of 10 331 compounds was good, with an R<sup>2</sup> of 0.94 and standard deviation of 0.47. The training set contained several perfluorocarbons (see Appendix C) and it is likely that the predicted value for PPVE falls within the applicability domain of the model.
- For the OPERA model, the output states that PPVE is within the applicability domain, with a local applicability domain index of 0.959 and confidence level of 0.786 indicating a reasonably high reliability. The OPERA model calculates log K<sub>OA</sub> directly from the linear free energy relationship (LFER) descriptor: Molecular linear free energy relationship (MLFER): solute gas-hexadecane partition coefficient (US EPA, 2021a). The internal training set of 202 chemicals ranges from log K<sub>AW</sub> values of around 1 to 12. The external validation set of 68 chemicals ranges from log K<sub>AW</sub> values of around -1.5 to -11. Both the internal training set of chemicals and the external validation set of chemicals contain structurally related substances to PPVE.

**Table 5.5 Predicted log K<sub>OA</sub> values for PPVE**

Source	Details	log K <sub>OA</sub>
<b>EPISuite™ (RSC, 2020)</b>	KOAWIN v1.10 Log K <sub>OW</sub> = 3.35 Log K <sub>AW</sub> = 2.55	0.797
<b>EPISuite™ (Environment Agency)</b>	KOAWIN v1.10 Log K <sub>OW</sub> = 4.00 Log K <sub>AW</sub> = 1.832	2.168
<b>OPERA</b>	Global applicability domain: Inside Local Applicability domain index: 0.959 Confidence Interval 0.786	1.96
<b>Environment Agency</b>	Log K <sub>OW</sub> = 4 Log K <sub>AW</sub> = 3.52	0.48

Note: Different log  $K_{AW}$  values used by each database may account for differences in log  $K_{OA}$ , this further illustrates the potential pitfalls of relying in QSAR data for modelling of the properties of the PFAS family.

### **5.5.3 Data from structural analogues**

There are no measured data for structural analogues.

### **5.5.4 Additional sources**

No relevant references were identified in the literature search.

### **5.5.5 Recommended value**

The EU REACH registration calculates a log  $K_{OA}$  of 0.46 without further details. The Environment Agency assumes this was generated using the relationship between log  $K_{AW}$  and log  $K_{OW}$ , the same method that the Environment Agency used. This information should be added to the REACH registration dossier.

Other predicted values from the open literature and generated by the Environment Agency ranged from 0.797 to 2.168, although the reliability of these predictions is uncertain. The values of 0.797 was derived in the EU REACH registration using an unknown EPISuite™ version with a log  $K_{OW}$  that differs to that recommended by the Environment Agency. The remaining values generated using predictions range from 1.96 to 2.168.

The Environment Agency notes that differences in the predicted values presented and the calculated value presented in the EU REACH registration and the Environment Agency are likely attributable to the use of different log  $K_{AW}$  values derived from the use of different QSAR software packages and versions of these.

The Environment Agency does not consider it appropriate to choose a single value from the estimated data range. For the purposes of this evaluation it is assumed that the log  $K_{OA}$  is around 2 and that variations in those values presented in the EU REACH registration and summarised in Section 5.5.2 are due to the use of different log  $K_{AW}$  values generated using different QSAR software packages and different versions of these.

## **5.6 Dissociation constant**

The EU REACH registration has not provided a value for this endpoint (ECHA, 2020b). The Environment Agency agrees that a dissociation constant is not relevant for PPVE as it has no ionisable functional groups. It will remain as a neutral compound at environmentally relevant pH.

## 6 Environmental fate properties

The same comments about sources of data, reliability scoring and use of supplemental information apply as for Section 5.

### 6.1 Degradation

#### 6.1.1 Abiotic degradation

##### 6.1.1.1 Hydrolysis

The EU REACH registration dossier includes an OECD TG 111 study carried out to GLP (Unpublished, 2017a; ECHA 2020b). The PPVE had an analytical purity of 98.5%. The study was performed in the absence of light at 3 temperatures (10, 20 and 50 °C) at pH 4, 7 and 9 under sterile conditions.

Three separate hydrolysis samples were prepared for each pH and temperature with the exception of those to be sampled at  $T_0$ , where 5 replicates were prepared. For each pH and temperature combination the concentration of PPVE was measured via GC/MS at 8 discrete time points excluding  $T_0$ . Test durations are presented in Table 6.1. Suitable blanks and spikes were prepared for test system monitoring. A robust analytical method is presented in the CSR that includes details of a multipoint calibration and a lower limit of quantification exceeding an order of magnitude below the accepted water solubility value.

The sampling strategy was designed to reduce any losses of PPVE from the test systems. Test vials were filled completely and sealed to minimise volatile loss of the test substance. Samples were prepared using 10  $\mu$ L aliquots of test system spiking solution (concentration not stated) that were added to non-method blank vials (MilliQ water). The nominal concentration applied to the further buffer solutions is not explicitly stated. After spiking, test system vials were vortex mixed and placed in an incubator/shaker set to the indicated temperature and a shaking speed of 100 rpm.  $T_0$  samples were aliquoted for analysis within 20-30 minutes after spiking. At each sampling interval, samples were aliquoted within 10 minutes of removal from the incubator. Analytical samples were prepared by inserting a disposable syringe/needle assembly through the vial's septum and withdrawing the desired volume that was then injected through the bonded septum-seal of a separate 40-mL vial containing 10-mL of MilliQ reagent water. The EU REACH registration notes that given the volatile nature of the test substance, it is assumed that the sample will rapidly transfer into the available headspace of an analysis vial and thus stop any further hydrolytic transformation.

The initial concentrations ( $T_0$ ), presented in Table 6.1, are below the water solubility of 1.8 mg/L (Section 5.3). pH measurements indicated that no variation greater than 0.3 units was observed in any sample.

**Table 6.1 Measured initial concentrations and test duration of the hydrolysis of PPVE at 10 °C, 20 °C and 50 °C, and pH 4, 7 and 9**

pH	10 °C	20 °C	50 °C
<b>4</b>	Average: 567 µg/L Range: ≥ 476 to ≤ 646 µg/L (RSD% = 15) Test duration: 79 h	Average: 723 µg/L Range: ≥ 402 to ≤ 1140 µg/L (RSD% = 43) Test duration: 76 h	Average: 440 µg/L Range: ≥ 331 to ≤ 587 µg/L (RSD% = 28) Test duration: 48 h
<b>7</b>	Average: 634 µg/L Range: ≥ 486 to ≤ 722 µg/L (RSD% = 15) Test duration: 79 h	Average: 420 µg/L Range: ≥ 297 to ≤ 644 µg/L (RSD% = 33) Test duration: 76 h	Average: 425 µg/L Range: ≥ 264 to ≤ 637 µg/L (RSD% = 40) Test duration: 48 h
<b>9</b>	Average: 590 µg/L Range: ≥ 393 to ≤ 937 µg/L (RSD% = 39) Test duration: 168 h	Average: 604 µg/L Range: ≥ 476 to ≤ 650 µg/L (RSD% = 12) Test duration: 168 h	Average: 456 µg/L Range: ≥ 388 to ≤ 500 µg/L (RSD% = 10) Test duration: 48 h

RSD: relative standard deviation

Rate constants (k) and half-lives (DT<sub>50</sub>) were calculated using pseudo-first order kinetics. These data along with associated 95% confidence limits (half-life in hours) and are presented in Table 6.2.

**Table 6.2 Rate constants (k), half-lives (DT<sub>50</sub>) and confidence limits (95% CI) of PPVE at 10 °C, 20 °C and 50 °C and pH 4, 7 and 9**

pH	10 °C	20 °C	50 °C
<b>4</b>	k: 0.016 h <sup>-1</sup> DT <sub>50</sub> : 43.4 h 95% CI: 37.9 to 50.9 h	k: 0.032 h <sup>-1</sup> DT <sub>50</sub> : 21.6 h 95% CI: 18.5 to 26.1 h	k: 0.061 h <sup>-1</sup> DT <sub>50</sub> : 11.4 h 95% CI: 10.1 to 13.1 h
<b>7</b> <b>(key result)</b>	k: 0.024 h <sup>-1</sup> DT <sub>50</sub> : 29.2 h 95% CI: 26.6 to 32.2 h	k: 0.022 h <sup>-1</sup> DT <sub>50</sub> : 33.3 h 95% CI: 27.3 to 42.5 h	k: 0.061 h <sup>-1</sup> DT <sub>50</sub> : 11.3 h 95% CI: 9.58 to 13.8 h
<b>9</b>	k: 0.021 h <sup>-1</sup> DT <sub>50</sub> : 32.6 h 95% CI: 30.1 to 35.4 h	k: 0.021 h <sup>-1</sup> DT <sub>50</sub> : 33.5 h 95% CI: 31.2 to 36.2 h	k: 0.062 h <sup>-1</sup> DT <sub>50</sub> : 11.2 h 95% CI: 9.71 to 13.1 h

The coefficient of determination for the first order kinetics linear regression equation ranged from 0.83 to 0.96.

No significant dependence on pH was identified for the rate constants or half-lives. This was confirmed by plotting [ln k] versus [1/T] to generate Arrhenius curves. The rate constants calculated were dependent on temperature.

Further work was performed to assess the formation of transformation products in the hydrolysis study. Saturated samples of sterilised pH 7 buffer were prepared by incubating for > 28 d (no temperature given). Aliquots of this solution were transferred to sterilised buffer in gas tight vials to remove test material from excess neat material. Incubation was performed for a further 13 days to allow for complete hydrolysis. The concentration of PPVE throughout this assessment is not reported.

Samples were analysed by <sup>19</sup>F-NMR only, to determine the hydrolysis products after > 28 days in the dark under the same conditions as the definitive hydrolysis study. <sup>19</sup>F-NMR analyses detected deprotonated perfluoropropionic acid (PFPA) and fluoride ions. The registration dossier notes that PFPA was detected at an average 0.00127 ± 0.00001% (wt.) and 0.00138 ± 0.00001% (wt.). This was equated to 12.7 and 13.8 parts per million (ppm). The fluoride ion was detected at an average concentration of 0.00021% (wt.), equating to 2.1 ppm. No details of how this calculation was performed are presented in the registration dossier.

The EU REACH registration rates the study to be reliable with restrictions, though does not explain why the study is not considered fully reliable.

### Discussion

The EU REACH registration has concluded that PPVE readily hydrolyses to PFPA and ionic fluorine. This contradicts data presented in the registration dossier for other endpoints, such as water solubility (Section 5.3.1), n-octanol/water partition co-efficient (Section 5.5.1) and aquatic toxicity endpoints (Section 7).

The Environment Agency recognises that vinyl ethers can be subject to hydrolysis under acidic conditions. However, evaluation of the study highlights several technical issues that suggest the reported half-lives could reflect a process other than hydrolysis (such as volatilisation following sampling). Further information to address these points may be available in the original study report, but a radiolabelled study could also be useful to provide a mass balance for the test system. As a first step, the Environment Agency recommends that the study report is re-evaluated and the robust study summary updated to address these issues. In the absence of such data, the Environment Agency considers it precautionary to assume that PPVE does not hydrolyse significantly in aquatic media for the purposes of this assessment. If the UK supplier can demonstrate that hydrolysis is relevant, they must update the robust study summaries for other related physico-chemical endpoints to explain how the results might be affected.

#### 6.1.1.2 Phototransformation in air

**Table 6.3 Summary of phototransformation in air**

Method	Results	Remarks	Reference
<p><b>Non-guideline study to determine reaction rate with hydroxyl radicals</b></p> <p><b>Not to GLP</b></p>	<p>Degradation rate constant</p> <p><math>3.36 \times 10^{-12} \text{ cm}^3 \text{ molecule}^{-1} \text{ sec}^{-1}</math> at 20 °C</p> <p>Transformation products: not measured</p>	<p>Registrant: 2 (key study)</p>	<p>Amedro <i>et al.</i> (2015a) cited in ECHA (2020b)</p>

Amedro *et al.* (2015a, 2015b) report a study to determine the phototransformation rate of PPVE with hydroxyl radicals as a function of temperature and pressure using a pulsed laser photolysis method. The test was conducted using PPVE with an analytical purity of 99.85% carried in N<sub>2</sub> or N<sub>2</sub>/O<sub>2</sub> as bath gases. Hydroxyl radicals were generated by photolysis of two different precursors, H<sub>2</sub>O<sub>2</sub> and HNO<sub>3</sub>. PPVE concentrations were stated to be far in excess of the hydroxyl radical concentrations, so that the reaction could be



assumed to follow first order kinetics. The decrease in hydroxyl radical concentration was measured by laser induced fluorescence and was used to estimate the reaction rate.

At room temperature (293.3 K, 20 °C), no differences were found in reaction rate for either precursor. In addition, no difference in reaction rate was found between the two pressures of 50 and 200 Torr (6 666 and 26 664 Pa) that were tested. However, the reaction rate constant decreased with temperature. The authors propose that the hydroxyl radical forms an adduct with the double bond that can either be stabilised by further reactions or return to the original substance. The authors state that the main initial products of PPVE phototransformation are predicted to be perfluoropropyl fluoroformate and carbonyl fluoride, but that the ultimate degradation products are expected to be PFPA and hydrofluoric acid (HF). The EU REACH registration uses the degradation rate constant reported by Amedro *et al.* (2015a) together with the calculation method given in ECHA (2016) to determine an atmospheric half-life of 4.8 days for PPVE. The EU REACH registration assigned a Klimisch score of 2 (reliable with restrictions) as they considered the study to be well documented and to meet generally accepted scientific principles, but that some details were lacking and it was not conducted to GLP.

#### *Predicted data*

The US EPA CompTox dashboard contains a predicted atmospheric hydroxylation rate of  $2.10 \times 10^{-12} \text{ cm}^3 \text{ molecule}^{-1} \text{ sec}^{-1}$  for PPVE generated from the OPERA software (US EPA, 2020a). However, PPVE is not considered to be within the applicability domain of the model by CompTox, so this prediction is not reliable.

The RSC ChemSpider portal contains a predicted atmospheric hydroxylation rate for PPVE generated from the AOPWin software (RSC, 2020). The predicted value is  $1.32 \times 10^{-12} \text{ cm}^3 \text{ molecule}^{-1} \text{ sec}^{-1}$ . Gomis *et al.* (2015) note that the predictive power of AOPWin for PFAS is limited. Although some fluorinated substances are included in the training set, based on comparisons of predicted and measured photodegradation rates for 7 fluorinated substances they expect that AOPWIN may underestimate the true half-life in air.

#### *Discussion*

The Environment Agency considers that the Amedro *et al.* (2015a) study is reliable with restrictions, and indicates that the substance will undergo phototransformation in air. Following the method given in ECHA (2016), the rate constant for degradation in air is  $0.145 \text{ d}^{-1}$ , which equates to a half-life of 4.78 days (115 hours). This value will be used for the purposes of this assessment. Although the predicted reaction rates are not fully valid, they are similar to the experimentally determined value.

##### *6.1.1.3 Phototransformation in water*

No studies on the phototransformation of PPVE in water are available from the EU REACH registration dossier or from published data sources.

#### 6.1.1.4 Phototransformation in soil

No studies on the phototransformation of PPVE in soil are available from the EU REACH registration dossier or from published data sources.

### 6.1.2 Biodegradation in water

#### 6.1.2.1 Measured data

**Table 6.4 Summary of screening biodegradation studies**

Method	Results	Reliability	Reference
<b>OECD TG 301D (Ready Biodegradability: Closed Bottle Test)</b>	Not readily biodegradable	Registrant: 1 (key study)	Unpublished (2014a) cited in ECHA (2020b)
<b>GLP</b>	7% degradation after 28 days based on O <sub>2</sub> consumption at 15 mg/L  1% degradation after 28 days based on O <sub>2</sub> consumption at 30 mg/L		

The biodegradation screening study in the EU REACH registration dossier is an OECD TG 301D (closed bottle test) study carried out to GLP (Unpublished, 2014a; ECHA 2020b). The test was conducted using PPVE with an analytical purity of 98.5%. The inoculum used in the study was from a municipal sewage treatment plant treating predominantly domestic sewage and the sludge was not pre-adapted to the test material. The test was carried out using two test concentrations, 15 mg/L and 30 mg/L over 28 days. The study also included blank controls, a positive control and toxicity controls. Degradation was monitored by measuring the dissolved oxygen concentration. Sodium acetate was used as a reference substance.

Degradation of the test substance was found to be 7% after 28 days at 15 mg/L and 1% after 28 days at 30 mg/L, showing that the substance did not meet the criteria to be considered readily biodegradable. The degradation of sodium acetate was found to reach 86% after 7 days and 104% after 14 days, which met the criteria to demonstrate that the sludge was sufficiently active for the test to be valid and the toxicity controls demonstrated that the test substance did not inhibit the activated sludge. The EU REACH registration gives the study a reliability rating of 1 (reliable without restriction).

#### 6.1.2.2 Predicted data

The US EPA CompTox dashboard contains a predicted biodegradation half-life of 4.44 days generated from the OPERA software (US EPA, 2020a), but notes that PPVE is outside of the applicability domain of this model, so the prediction is not reliable.

The RSC ChemSpider portal contains a prediction for the probability of rapid biodegradation for PPVE generated from the BIOWIN software (RSC, 2020). All 7 BIOWIN models predict that PPVE will not biodegrade readily. The BIOWIN model predictions are based on the molecular fragments “carbons with four bonds that are not attached to hydrogens”, “aliphatic ether C-O-C” and “trifluoromethyl (-CF<sub>3</sub>) group”. The Environment Agency considers that these fragments describe PPVE adequately and therefore that this substance is within the domain of these models.

#### *6.1.2.3 Data from structural analogues*

Not considered as valid data for the endpoint are available for the substance under evaluation.

#### *6.1.2.4 Discussion*

The Environment Agency notes that the available experimental study met the validity criteria and that this study followed the standards in OECD TG 301D. This guideline is suitable for testing substances which are poorly water soluble or volatile. The concentration of PPVE used in this study was around 10 times higher than the reported water solubility limit of 1.8 mg/L (Section 5.3.1). No solvent or emulsifying agent was used, in accordance with the test guideline. Although no information is given on whether any other method was used to disperse the test material, the Environment Agency considers that the study is reliable. The data indicate that the substance is not readily biodegradable as only low levels of degradation were observed when using a standard test method.

The experimental data indicate that the substance is not readily biodegradable as only low levels of degradation were observed when using a standard test method. This finding is supported by BIOWIN predictions.

### **6.1.3 Biodegradation in sediment**

This is a standard REACH information requirement at a supply level of 100 to 999 tonnes/year for substances with a high potential for adsorption to sediment, although the study does not need to be conducted if the Registrant considers direct and indirect exposure of sediment is unlikely. No relevant information is available in the EU REACH registration dossier or from published data sources. No argument is provided in the EU REACH registration for the omission of this information.

### **6.1.4 Biodegradation in soil**

This is a standard REACH information requirement at a supply level of 100 to 999 tonnes/year for substances with a high potential for adsorption to soil, although the study does not need to be conducted if the Registrant considers direct and indirect

exposure of sediment is unlikely. No relevant information is available in the EU REACH registration dossier or from published data sources. No argument is provided in the EU REACH registration for the omission of this information.

### **6.1.5 Summary and discussion on degradation**

Further information to clarify the behaviour of PPVE in water is required before a definitive evaluation of its hydrolytic stability can be made. In the absence of such information, the Environment Agency assumes that PPVE is hydrolytically stable over the environmentally relevant pH range of 4 to 9. PPVE degrades in air with an experimentally derived half-life of 4.78 days, to form PFPA. No information is available on its phototransformation potential in water or soil.

A 28-day biodegradation screening study is available which the EU REACH registration considers fully valid. The study indicates that the substance achieved a low level of mineralisation (up to 7%) over 28 days. The EU REACH registration therefore concludes that PPVE is not readily biodegradable.

There are no environmental simulation data so a realistic half-life in relevant media cannot be established. Highly fluorinated substances generally degrade very slowly under relevant environmental conditions. The screening biodegradation result is consistent with this.

Based on the chemical structure and evidence from abiotic studies, the EU REACH registration concludes that it is likely that PFPA will be the terminal (“arrowhead”) transformation product. The EU REACH registration assessed the persistence of PFPA as part of the PBT assessment of PPVE. Two ready biodegradation studies showed very low levels of mineralisation (<3%) and hydrolysis and photolysis are not expected to be relevant degradation pathways.

By analogy with other perfluorocarboxylic acids, the Environment Agency expects PFPA to be very stable with an environmental half-life of years or longer (ECHA, 2017). The Environment Agency has not sought further information for the purposes of this assessment. The main source is expected to be photodegradation of PPVE, although very slow biotic degradation of PPVE is also expected to result in formation of PFPA.

## **6.2 Environmental distribution**

### **6.2.1 Adsorption/desorption**

#### *6.2.1.1 Measured data*

The EU REACH registration dossier includes brief details of an adsorption/desorption screening study according to OECD TG 121 using the HPLC method (Unpublished,

2014b; ECHA, 2020b). The organic carbon-water partition coefficient ( $K_{OC}$ ) could not be determined because the test substance could not be detected using UV absorbance.

### 6.2.1.2 Predicted data

**Table 6.5 Summary of predicted adsorption/desorption**

Method	Results	Reliability	Reference
<b>Non-guideline study. Calculation using 'predominantly hydrophobics' equation provided in ECB (2003)</b>	log K <sub>oc</sub> 3.34  Based on a log K <sub>ow</sub> of 4 and the relationship $\log K_{oc} = 0.81 \log K_{ow} + 0.10$	Registrant: 2 (key study)	Unpublished (2014b) cited in ECHA (2020b)
<b>OPERA</b>	log K <sub>oc</sub> 3.22	QSAR, not included in the registration dossier	US EPA (2020a)
<b>PCKOCWIN software</b>	log K <sub>oc</sub> 2.99	QSAR, not included in the registration dossier	RSC (2020)

The EU REACH registration dossier includes a calculated log K<sub>oc</sub> of 3.34 (Unpublished, 2014b; ECHA, 2020b) based on the experimentally determined log K<sub>ow</sub> and the equation given in ECB (2003).

The US EPA CompTox dashboard contains a predicted K<sub>oc</sub> of 1 660 (log K<sub>oc</sub> 3.22) generated from the OPERA software (US EPA, 2020a). PPVE is stated to be within the applicability domain of the model by CompTox but the nearest neighbour analogues of PPVE from the training set are not fluorinated compounds, so this prediction is uncertain.

The RSC ChemSpider portal contains a predicted K<sub>oc</sub> of 975.7 (log K<sub>oc</sub> 2.99) for PPVE generated from the PCKOCWIN software (RSC, 2020). It is unclear whether this prediction is based on the Molecular Connectivity Index (MCI) method or on the log K<sub>ow</sub> method. If the latter, this value should not be used as it would have been based on a predicted log K<sub>ow</sub> value of 3.35. *In silico* predicted values should always be treated with caution where substances in the training set and external test set are not visible. For the PCKOCWIN model this information was not available. Therefore, no assessment of the applicability could be performed.

### 6.2.1.3 Data from structural analogues

Data were not available regarding the adsorption/desorption of the structural analogue PEVE.

### 6.2.1.4 Recommended value

A measured log K<sub>oc</sub> value is not available for PPVE, because the substance could not be detected using the chosen analytical method. Based on the predicted values generated in

the EU REACH registration dossier and by the Environment Agency, the log  $K_{oc}$  appears to be in the range 3.22 to 3.34. Although these values are very similar, there is significant uncertainty in their reliability. The Environment Agency recommends that, subject to confirmation of lack of hydrolysis (see Section 6.1.5), a new experimental log  $K_{oc}$  study is performed to provide clarity (recognising that there may be technical challenges due to PPVE's volatility). In the absence of such data, the log  $K_{oc}$  of 3.34 as proposed in the EU REACH registration will be used for the purposes of this assessment.

## 6.2.2 Volatilisation

### 6.2.2.1 Measured data

**Table 6.6 Summary of Henry's Law constant studies**

Method	Results	Reliability	Reference
<b>Non-guideline study: Equilibration method  Not to GLP</b>	Henry's Law constant 3 200 (dimensionless) at 22.6 °C and 760 mmHg (101.3 kPa)	Registrant: 1 (key study)	Unpublished (2015) cited in ECHA (2020b)

There is no standard OECD TG to determine the Henry's Law constant. The Henry's Law constant in the EU REACH registration dossier is determined using an equilibration method that used the ratio of PPVE in the gas phase and the water phase of a test system to calculate the value (Unpublished, 2015; ECHA, 2020b). The test was conducted using PPVE with an analytical purity of 98.5%. Duplicate test vessels containing water with 30, 50 or 70% headspace were dosed with PPVE gas and analysed over 7 days by purge-and-trap GC/MS. Information on how the PPVE gas was generated is not available from the publicly available EU REACH registration database. The concentration in both the water phase and gas phase was determined and the Henry's Law constant for each sampling point calculated. The average dimensionless Henry's Law constant was reported to be 3 200 at 22.6 °C and 760 mmHg (101.3 kPa). The EU REACH registration gives the study a reliability rating of 1 (reliable without restriction).

### 6.2.2.2 Predicted data

**Table 6.7 Summary of predicted Henry's Law constant**

Method	Results	Reference
<b>Calculated based on vapour pressure, water solubility and molecular weight</b>	79.8 atm m <sup>3</sup> /mole	ECHA (2016)
<b>HENRYWIN</b>	8.74 atm m <sup>3</sup> /mole bond estimate	RSC (2020)

	could not be estimated based on group estimate	
<b>OPERA</b>	$1.8 \times 10^{-11}$ atm m <sup>3</sup> /mole	US EPA (2020a)

The Environment Agency has calculated a Henry's Law constant for PPVE using a number of available QSARs.

Following Equation R.16-4 of ECHA (2016) a Henry's Law constant of 79.8 atm m<sup>3</sup>/mole is calculated for PPVE based on the vapour pressure (55 kPa; 0.54 atm), water solubility (1.8 mg/L) and molecular weight of PPVE (266.04 g/mole).

RSC (2020) reports a Henry's Law constant generated by the HENRYWIN module of EPISuite™ (US EPA, 2012) using two different methods, a bond estimate approach and a group estimate approach. Only a bond estimate could be made for PPVE. There is no defined applicability domain for the bond estimate in HENRYWIN. However, the molecular weight and predicted Henry's Law constant are within the range of the training set compounds, and all the functional groups present in PPVE are included within the bond estimate method.

The US EPA CompTox dashboard contains a predicted Henry's Law constant of  $1.8 \times 10^{-11}$  atm m<sup>3</sup>/mole generated from the OPERA software (US EPA, 2020a). PPVE is stated to be outside the applicability domain of the model by CompTox, so this prediction is not reliable.

#### 6.2.2.3 Data from structural analogues

As a reliable measured value is available for PPVE, information from structural analogues was not considered.

#### 6.2.2.4 Recommended value

Although an original study report has not been reviewed, the Environment Agency considers that the study cited in the EU REACH registration dossier is likely to be reliable. The average dimensionless Henry's Law constant is reported as 3 200 at 22.6 °C and 760 mmHg (101.3 kPa).

The EU REACH registration converted this value to 78.3 atm.m<sup>3</sup>/mole ( $7.93 \times 10^6$  Pa.m<sup>3</sup>/mol), but the Environment Agency cannot replicate this calculation. Using Equation R.16-5 in ECHA (2016), the Environment Agency calculates a Henry's Law constant of 77.6 atm.m<sup>3</sup>/mole ( $7.87 \times 10^6$  Pa.m<sup>3</sup>/mole). This value is very similar to the calculated value based on the vapour pressure and water solubility of PPVE. A value of 77.6 atm.m<sup>3</sup>/mole ( $7.87 \times 10^6$  Pa.m<sup>3</sup>/mole) will be used in this assessment and indicates that PPVE would be expected to volatilise significantly from aqueous solutions.



### 6.2.3 Distribution modelling

**Table 6.8 Summary of distribution modelling**

Method	Percent distribution in media	Reliability	Reference
<b>Non-guideline study: EQC v1.01 Mackay Level III model</b>	Air (%): 99.996	Registrant: 2 (key study)	Unpublished (2017b) cited in ECHA (2020b)
	Water (%): 0		
	Soil (%): 0.004		
	Sediment (%): 0		
	Suspended sediment (%): 0		
	Biota (%): 0		
	Aerosol (%): 0		

The EU REACH registration dossier included the results of a Level III fugacity model to predict the distribution of PPVE in the environment (Unpublished, 2017b; ECHA 2020b). The model assumed a release of 100 kg/year to air. The input parameters used were:

Molar mass:	266 g/mol
Temperature:	25 °C
Water solubility:	1.87 g/m <sup>3</sup>
Vapour pressure:	67 000 Pa
Henry's Law coefficient:	7.93 x 10 <sup>6</sup> Pa.m <sup>3</sup> /mol
log Kow:	4.0
Melting point:	-80 °C
Reaction half-life estimates:	Air: 115 hours
	Water: 29.1 hours
	Soil: 7 390 hours
	Sediment: 2.4 x 10 <sup>7</sup> hours

On the basis of these input parameters and assumptions the model predicts that the substance will mostly reside in the atmosphere, with a very small fraction (<0.1%) in soil.

The Environment Agency has not re-run the distribution modelling, but notes that some of the physico-chemical input parameters and half-life values used in the EU REACH registration would need to be updated based on this assessment if additional distribution modelling was performed. In particular, the half-lives in water, soil and sediment have not been fully justified in the EU REACH registration.

### 6.2.4 Long-range transport

The OECD has produced a decision support tool for estimating the long-range transport potential (LRTP) of organic chemicals at a screening level (Wegmann *et al.*, 2009). It is a steady state non-equilibrium model in a standardised evaluative environment, and predicts

three characteristics that can be used to provide an indication of the LRTP of a substance: Characteristic Travel Distance (CTD), Transfer Efficiency (TE) and overall persistence (P<sub>ov</sub>).

To estimate the LRTP of PPVE, the Environment Agency has performed calculations using the input parameters indicated in Table 6.9.

**Table 6.9 Estimated long-range transport potential of PPVE**

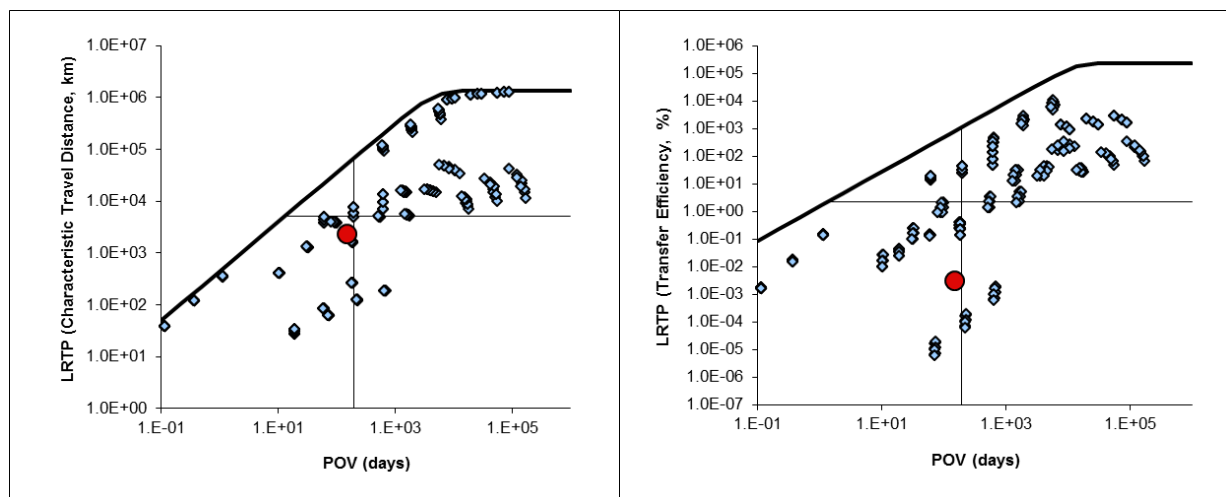
<b>Input Parameter</b>	<b>Value</b>
<b>Molecular mass (g/mol)</b>	266.04
<b>Log K<sub>AW</sub><sup>a</sup></b>	3.52
<b>Log K<sub>ow</sub></b>	4
<b>Half-life in air (hours)</b>	115
<b>Half-life in water (hours)<sup>b</sup></b>	2.1 x 10 <sup>41</sup>
<b>Half-life in soil (hours)<sup>b</sup></b>	2.1 x 10 <sup>41</sup>
<b>LRTP output parameter</b>	
<b>Characteristic Travel Distance (km)</b>	2 385
<b>Transfer Efficiency (%)</b>	0.003
<b>P<sub>ov</sub> (days)</b>	146

Note: a - This is the log of the dimensionless HLC calculated using Equation R.16-5 of ECHA (2016).

b -The upper bound value for biodegradation of a non-readily biodegradable substance in EUSES is 1 x 10<sup>40</sup> days to represent infinity (equivalent to 2.1 x 10<sup>41</sup> hours).

The OECD LRTP screening tool allows comparisons of the CTD and TE characteristics for a range of substances, some of which are POPs, provided in Figure 6.1.

**Figure 6.1 Long-range transport potential of PPVE for predictive modelling**



Note: In the left hand graph the x axis is overall persistence in days (Pov) and the y axis is the Characteristic Travel Distance (km). In the right hand graph the x axis is overall persistence in days (Pov) and the y axis is the Transfer Efficiency (%).

Based on this screening tool, it appears that PPVE would be of lower concern for long-range transport as it falls into the lower left hand quadrant of Figure 2. However, the potential for long-range transport is within the range of other substances that are POPs so cannot be excluded. In addition, evidence of occurrence (or not) of PPVE in the Arctic and other remote regions also needs to be taken into account (noting the proximity of industrial activity and population centres). This is beyond the scope of this evaluation.

PPVE is a source of PFPA in air (see Section 6.1.1), and the transport of that substance is also relevant (but has not been considered further by the Environment Agency).

## 6.3 Bioaccumulation

### 6.3.1 Bioaccumulation in aquatic organisms

#### 6.3.1.1 Measured data

This is a standard REACH information requirement at a supply level of 100 to 999 tonnes/year, although a study need not be conducted if direct and indirect exposure of the aquatic compartment is unlikely. No information for PPVE is available in the EU REACH registration dossier.

#### 6.3.1.2 Predicted data

**Table 6.10 Summary of predicted fish bioconcentration factors (BCF)**

Method	Results	Reference
OPERA	37.5	US EPA (2020a)
BCFWIN	75.54 based on log K <sub>ow</sub> 3.35	RSC (2020)
Calculation based on log K <sub>ow</sub>	501 based on log K <sub>ow</sub> 4	ECHA (2017a)

The log K<sub>ow</sub> of 4 suggests that PPVE may be moderately bioaccumulative in aquatic gill-breathing organisms.

The US EPA CompTox dashboard contains predicted fish BCF for PPVE generated from the OPERA software (US EPA, 2020a). The OPERA model predicts a BCF of 37.5, but notes that PPVE is outside of the applicability domain of this model, so the prediction is not reliable.

The RSC ChemSpider portal contains a predicted BCF of 75.54 for PPVE generated from the BCFWIN software (RSC, 2020). There is no defined applicability domain for BCFWIN but the molecular weight and log K<sub>ow</sub> are within the range of the training set compounds. However, the calculated BCF is based on a predicted log K<sub>ow</sub> of 3.35, so may be an under-estimate.

The Environment Agency has used the experimental log K<sub>ow</sub> of 4 to calculate a BCF of 501 using the equation given in R.7.10.3.2 of ECHA (2017a). The reliability of this value is unknown as the applicability domain is not stated, although the log K<sub>ow</sub> is within the range of the training set compounds.

#### 6.3.1.3 Data from structural analogues

No data relating to bioaccumulation were presented in the EU REACH registration dossier for the structural analogue PEVE.

#### 6.3.1.4 Recommended value

A measured BCF value is not available for PPVE. Based on the predicted values generated in the EU REACH registration dossier and by the Environment Agency, the range of modelled BCF appears to be around or below 500, although the performance of existing predictive methods for highly fluorinated substances is questionable. Further information to clarify the behaviour of PPVE in water (see Section 6.1.5) is required before an evaluation of its aquatic bioaccumulation potential can be finalised.

### 6.3.2 Terrestrial bioaccumulation

The EU REACH registration has not assessed the potential for terrestrial bioaccumulation as this is not a standard information requirement.

Evidence from other functionalised highly fluorinated substances (e.g. perfluorocarboxylic acids) suggests that terrestrial bioaccumulation may be more relevant than aquatic bioaccumulation, due to protein binding mechanisms. However, this might not apply to a neutral substance like PPVE.

In terms of bioaccumulation in air breathing organisms, the screening criteria are  $\log K_{OW} > 2$  and  $\log K_{OA} > 5$ . Based on the values discussed in Section 5, the  $\log K_{OW}$  exceeds the threshold but the  $\log K_{OA}$  does not. There is some uncertainty in the  $\log K_{OA}$  value, but this criterion does not appear to be met based on the available information.

No information on bioaccumulation is available from the available mammalian toxicity studies.

### **6.3.3 Summary and discussion of bioaccumulation**

The  $\log K_{OW}$  of 4 suggests that PPVE may be moderately bioaccumulative in aquatic gill-breathing organisms. An experimental study is not available, and the predicted BCF values (at or below 500) are uncertain. Further information to clarify the behaviour of PPVE in water is required before an evaluation of its aquatic bioaccumulation potential can be finalised.

The bioaccumulation potential of PPVE in air-breathing organisms is uncertain but there are no indications of concern based on currently available data.

## 7 Ecotoxicology

The same comments about sources of data, reliability scoring and use of supplemental information apply as for Section 5. The Environment Agency notes that PPVE has a low solubility in water (Section 5.3) and high Henry's Law constant (Section 6.2.2) which indicates that the substance will tend to volatilise from water to air. In addition, the EU REACH registration considers that the substance hydrolyses with a half-life of 21.6 to 33.5 hours at 20 °C (the Environment Agency considers that further justification is required to substantiate the level of hydrolysis assumed; see Section 6.1.1). Measurement of test concentrations is therefore very important for aquatic toxicity studies, as exposure concentrations may be difficult to maintain (especially in static test systems). The ecotoxicity of the apparent hydrolytic transformation product (PFPA) may also be a relevant consideration.

There are no aquatic toxicity data for the analogue PEVE on the ECHA database, as the studies could not be performed for technical reasons (the substance is a gas).

### 7.1 Aquatic compartment (including sediment)

#### 7.1.1 Fish

##### 7.1.1.1 Short-term (acute) toxicity

Table 7.1 Summary of acute toxicity to fish

Method	Species	Analytical method	Results	Reliability	Reference
OECD TG 203 (static)	Zebrafish <i>Danio rerio</i>	Confidential	Limit test 96-h LC <sub>50</sub> >0.52 mg/L  based on the arithmetic mean measured concentration; mortality endpoint	Registrant: 1 (key study)	Unnamed (2017) cited in ECHA (2020b)

One acute fish toxicity study is included in the EU REACH registration dossier as the key study (Unnamed, 2017, cited in ECHA, 2020b). This acute fish toxicity study was conducted according to OECD TG 203 and GLP using *Danio rerio* (Zebrafish) and PPVE with an analytical purity of 98.5% (w/w). A limit test was performed using static exposure. No justification was provided for the use of static conditions.

Test solutions were prepared by slowly rotating 3.3 L septum-sealed screw cap flasks completely filled with a nominal 10 mg/L loading rate of the test substance in adjusted ISO medium for 5 days, followed by a 2 day settling period. Revolutions per minute were not detailed. The EU REACH registration states that this pre-treatment was used because the test substance is extremely volatile. Resulting test solutions were clear and colourless, with visible droplets of undissolved test substance. It is presumed that undissolved test chemical was not separated from the aqueous fraction as no mention is made of extracting final solutions from the stock solution and the same sized glass flasks were used for the exposure as for the test solution preparation.

Analytical verification was undertaken using duplicate samples from one replicate of the control and the single test concentration at the start and end of the test. The analytical method, as well as the measured concentrations at the start and end of the test are not detailed in the EU REACH registration dossier. The arithmetic mean measured concentration was stated to be 0.52 mg/L which the EU REACH registration considered was the maximum soluble concentration in the test medium.

Nine fish (3 replicates of 3 animals) were exposed to the nominal 10 mg/L loading and the control for 96 hours in the closed 3.3 L glass flasks. Two out of the 9 fish in the test concentration died during the 96-hour test period. Relative to the control group, all fish in the test concentration were observed to swim slowly from 72 hours onwards. The 96-h LC<sub>50</sub> was reported to be >0.52 mg/L based on the arithmetic mean measured concentration obtained at the start of the test. The EU REACH registration considers this study to be reliable without restriction (Klimisch 1).

No control mortality was observed, meeting the validity criterion for <10% mortality in the control. While the EU REACH registration suggests that dissolved oxygen (DO) met the validity criterion for ≥60% of the air saturation value (ASV), the Environment Agency notes that the lowest DO concentration (4.9 mg/L) was borderline around this validity criterion at the test temperatures that ranged from 21.8 - 22.0 °C. The closed system is likely to have contributed to the low DO concentrations, despite the larger test volumes with a biomass loading of 0.09 g fish/L compared with the OECD TG 203 standard maximum loading of 0.8 g/L for static test systems (OECD, 2019). Issues with DO were also observed in a preliminary test where it decreased from 8.5 to 0.7 mg/L in the saturated solution after 72 hours when all fish in this treatment were found dead. These issues suggest that semi-static or flow-through renewal of the test solutions may have been more suitable to maintain oxygen concentrations within guideline values (OECD, 2019). However, DO did not affect the LC<sub>50</sub> in the definitive study due to the low level of mortality observed in the test concentration and because no mortality occurred in the control.

According to OECD TG 203, limit tests should be performed using at least 7 fish in the control and treatment group without tank replication. The use of 3 replicates of 3 animals in this test is therefore a non-standard setup which could have affected the statistics. Based on confidential information on the observations in each of the replicates, the Environment Agency considers that the non-standard test setup did not affect the reliability

of the study endpoint. Also contrary to standard practice (OECD, 2019), the undissolved test material was not removed prior to the test. The presence of undissolved droplets following the pre-treatment suggests a saturated solution was likely to have been achieved. Given that no mortality in the controls occurred, DO was close to or above 60% of the ASV and mortality was below 50% in the test concentration, the Environment Agency considers that the presence of undissolved test material in the final test solution, while not ideal, probably did not affect the reliability of the endpoint.

The test design was intended to reduce volatile losses and achieve the maximum dissolved concentration of the test substance. As such, the mean measured concentration was within one order of magnitude of the limit of water solubility of 1.8 mg/L (Section 5.3).

The pH was measured daily during the test and varied between 7.1 and 8. The absence of a significant change in pH, for example to acidic conditions might suggest that PFPA was not formed in significant quantities, although it is not possible to verify this without further data.

All other study parameters were comparable to those recommended in OECD TG 203.

The Environment Agency considers that the study is reliable for the purposes of this assessment given that there were no significant deviations from the study guideline and suitable measures were taken to reduce volatile losses of the test substance and achieve the maximum dissolved concentration of PPVE. However, PPVE is poorly soluble in water and may hydrolyse. It has not been possible for the Environment Agency to verify the analytical measurements based on the information in the EU REACH registration. Therefore, the Environment Agency considers that information on the measured concentrations at the start and end of the test and details regarding the analytical method would be useful to support the quoted mean measured endpoint.

#### *Transformation products*

The EU REACH registration considers that PPVE hydrolyses with a half-life of 21.6 to 33.5 hours at 20 °C (Section 6.1.1.1), which would suggest that there could have been a significant loss of test concentration over 96 hours under static conditions. Two freshwater fish toxicity studies conducted with the suggested hydrolysis product PFPA are therefore noted in the EU REACH registration dossier for PPVE in the PBT assessment section. The results of these were both stated to be greater than the  $E_rC_{50}$  of 10.4 mg/L and the NOEC of 3.47 mg/L values determined in algal toxicity tests performed with PFPA (i.e. fish are less acutely sensitive than algae). No additional information on the study methods or endpoints are currently available. Overall, the data suggest that PFPA has a low acute toxicity to fish.

#### *7.1.1.2 Long-term (chronic) toxicity*

Long-term fish toxicity tests on fish are not available.



## 7.1.2 Aquatic invertebrates

### 7.1.2.1 Short-term (acute) toxicity

**Table 7.2 Summary of acute toxicity to aquatic invertebrates**

Method	Species	Analytical method	Results	Reliability	Reference
<b>OECD TG 202 (static)</b>	<i>Daphnia magna</i>	Confidential	Limit test 48-h EC <sub>50</sub> >0.622 mg/L  based on the arithmetic mean measured concentration; mobility endpoint	Registrant: 1 (key study)	Unnamed (2017) cited in ECHA (2020b)

The EU REACH registration dossier includes one acute invertebrate toxicity study for *Daphnia magna* as the key study (Unnamed, 2017, cited in ECHA, 2020b). The study was performed according to OECD TG 202 and GLP and used PPVE with an analytical purity of 98.7% (w/w). A limit test was performed using static exposure. As a possible justification for the use of the static test system, the EU REACH registration considered that the test substance is stable for the test duration, although they consider that it undergoes slow hydrolysis in neutral or alkaline solution.

Test solutions were prepared by slowly rotating 42.5 mL septum-sealed screw cap vials completely filled with a nominal 100 mg/L loading rate of the test substance in ISO medium for 7 days, and then centrifuging at 500 × g for 90 minutes. Revolutions per minute for the 7 days before centrifuging were not detailed. The EU REACH registration states that this pre-treatment was used because the test substance is extremely volatile. Resulting test solutions were clear and colourless, with a visible small droplet of undissolved test substance at the bottom. Undissolved test chemical was not separated from the aqueous fraction.

Analytical verification was undertaken using extra sample vials for the control and test concentration at the start and end of the test. The analytical method, as well as the measured concentrations at the start and end of the test, are not detailed in the EU REACH registration dossier. The arithmetic mean measured concentration was reported as 0.622 mg/L which the EU REACH registration considered the maximum soluble concentration in the test medium.

Twenty daphnids (4 replicates of 5 animals) were exposed to the single test concentration and the control for 48 hours in the closed 42.5 mL glass vials. No immobilisation was observed. Therefore, the 48-h EC<sub>50</sub> was reported as >0.622 mg/L expressed as the mean

measured concentration. The EU REACH registration considers that this study is reliable without restriction (Klimisch 1).

The validity criterion for <10% immobilisation in the control and  $\geq 3$  mg/L of DO in the control and test vessels at the end of the test were met. Contrary to standard practice (OECD, 2019), undissolved test material was not removed prior to the test. The presence of undissolved droplets following the pre-treatment suggests a saturated solution was likely to have been achieved. However, the Environment Agency considers that the presence of undissolved test material in the final test solution, while not ideal, probably did not affect the reliability of the endpoint as no immobilisation occurred in the control and in the test concentration.

The test design was intended to reduce volatile losses and achieve the maximum dissolved concentration of the test substance. As such, the mean measured concentration was within one order of magnitude of the limit of water solubility of 1.8 mg/L (Section 5.3).

The pH was measured at the start and end of the test and varied between 8.1 and 8.3. The absence of a significant change in pH, for example to acidic conditions might suggest that PFPA was not formed in significant quantities, although it is not possible to verify this without further data.

All other study parameters were comparable to those recommended in OECD TG 202.

The Environment Agency considers that the study is reliable for the purposes of this assessment given that there were no significant deviations from the study guideline and suitable measures were taken to reduce volatile losses of the test substance and achieve the maximum dissolved concentration of PPVE. However, PPVE is poorly soluble in water and may hydrolyse. It has not been possible for the Environment Agency to verify the analytical measurements based on the information in the EU REACH registration. Therefore, the Environment Agency considers that information on the measured concentrations at the start and end of the test and details regarding the analytical method would be useful to support the quoted mean measured endpoint.

#### *Transformation products*

The EU REACH registration considers that PPVE hydrolyses with a half-life of 21.6 to 33.5 hours at 20 °C (Section 6.1.1.1), which would suggest that there could have been a significant loss of test concentration over 96 hours under static conditions. An acute *D. magna* toxicity study conducted with PFPA is noted in the EU REACH PPVE registration dossier in the PBT assessment section. The results of these were greater than the  $E.C_{50}$  of 10.4 mg/L and the NOEC of 3.47 mg/L derived from algal toxicity tests with PFPA (i.e. *D. magna* are less acutely sensitive than algae). No additional information on the methods or endpoints are currently available. Overall, the data suggest that PFPA has a low acute toxicity to aquatic invertebrates.

### 7.1.2.2 Long-term (chronic) toxicity

Long-term invertebrate toxicity tests on invertebrates are not available.

## 7.1.3 Algae and aquatic plants

Table 7.3 Summary of toxicity to algae

Method	Species	Analytical method	Results	Reliability	Reference
OECD TG 201 (static)	<i>Pseudo-kirchneriella subspicata</i>	Confidential	Limit test 72-h E <sub>r</sub> C <sub>50</sub> >0.458 mg/L 72-h E <sub>r</sub> C <sub>10</sub> >0.458 mg/L 72-h NOE <sub>r</sub> C <0.485 mg/L based on the geometric mean measured concentration; growth rate inhibition endpoint	Registrant: 1 (key study)	Unnamed (2017) cited in ECHA (2020b)

One algal growth inhibition study is included in the EU REACH registration dossier (Unnamed, 2017, cited in ECHA, 2020b). This study was performed as a limit test according to OECD TG 201 and GLP using *Pseudokirchneriella subcapitata* and PPVE with an analytical purity of 98.5% (w/w).

Test solutions were prepared by slowly rotating 42.5 mL septum-sealed screw cap vials completely filled with a nominal 100 mg/L loading rate of the test substance in OECD TG 201 adjusted growth medium for seven days, and then centrifuging at 500 × g for 90 minutes. Revolutions per minute for the 7 days before centrifuging were not detailed. No justification for this pre-treatment is provided in the EU REACH registration (but based on the fish and invertebrate studies, the Environment Agency assumes it was to limit volatilisation). The OECD TG 201 test medium was adjusted to contain 300 mg/L of sodium bicarbonate (NaHCO<sub>3</sub>) and 6mM HEPES buffer with a final pH of 7.1 ± 0.3. This NaHCO<sub>3</sub> buffer system is recommended to maintain dissolved CO<sub>2</sub> concentrations without pH drift to minimise the growth limiting effects of the closed system (OECD, 2019). Resulting test solutions were clear and colourless, with a visible small droplet of undissolved test substance at the bottom. Undissolved test chemical was not separated from the aqueous fraction.

Analytical verification was undertaken using duplicate sample vials for the control and test concentration at the start and end of the test. The analytical method, as well as the measured concentrations at the start and end of the test, are not detailed in the EU REACH registration dossier. The geometric mean measured concentration was reported as 0.458 mg/L which was considered the maximum soluble concentration in the test medium.

Six replicates were used for the single test concentration and the control. Tests were initiated by injecting algal suspension through the septum while a vent needle allowed an equal volume of medium to be displaced. The resulting initial cell density was  $10^4$  cells/mL.

Cell density in the control cultures increased by a factor of 119 within the 72 hour test period and the Environment Agency has calculated a coefficient of variation of the average specific growth rates in the control replicates of 1.65%, meeting the OECD TG 201 validity criteria for these parameters. However, the mean coefficient of variation for the section-by-section specific growth rates in the control of 43.9% exceeded the validity criterion of 35%. The EU REACH registration considered that the exceedance of this validity criterion was unavoidable given the sealed flasks used to test this volatile, poorly soluble substance and the results were the 'best possible'. All the other test parameters were comparable to the recommendations in OECD TG 201 with pH ranging from 7.4 to 7.9 and temperature ranging from 21.7 to 22.8 °C.

The 72-h  $E_rC_{50}$  was reported to be  $>0.458$  mg/L based on the geometric mean measured concentration. The 72-h  $NOE_rC$  was  $<0.458$  mg/L based on the geometric mean measured concentration due to a significant reduction in growth rate by 5.5%. The EU REACH registration considered that this inhibition of growth rate was not biologically relevant as the  $E_rC_{10}$  is  $>0.458$  mg/L based on the geometric mean measured concentration. The Environment Agency notes that there is a regulatory preference for  $E_rC_{10}$  statistical endpoint as opposed to  $NOE_rC$  values to describe chronic toxicity to algae (OECD, 1998, 2006 & 2011; ECHA, 2008, 2017b & 2017c). This is to address the arbitrary nature of a NOEC which is dependent on the test concentration chosen. In this instance, the effect on growth rate was below 10% at the limit of solubility. The EU REACH registration considers that this study is reliable without restriction (Klimisch 1) and the key study for the toxicity of PPVE to algae and aquatic plants.

Contrary to standard practice (OECD, 2019), undissolved test material was not removed prior to the test. The presence of undissolved droplets following the pre-treatment suggests a saturated solution was likely to have been achieved. However, as growth inhibition was below 10% in the test concentration and two of the three OECD TG 201 validity criteria for control growth were met, the Environment Agency considers that the presence of undissolved test material in the final test solution, while not ideal, probably did not affect the reliability of the endpoint.

The test design was intended to reduce volatile losses and achieve the maximum dissolved concentration of the test substance. As such, the mean measured concentration was within one order of magnitude of the limit of water solubility of 1.8 mg/L (Section 5.3).

The pH varied between 7.4 and 7.9, although the measurement interval is not clear. The absence of a significant change in pH, for example to acidic conditions might suggest that PFPA was not formed in significant quantities, although it is not possible to verify this without further data.

The Environment Agency considers that the study is sufficiently reliable for the purposes of this assessment given that most of the study parameters are in line with OECD TG 201 recommendations and suitable measures were taken to reduce volatile losses of the test substance and achieve the maximum dissolved concentration of PPVE. However, PPVE is poorly soluble in water and may hydrolyse. It has not been possible for the Environment Agency to verify the analytical measurements based on the information in the EU REACH registration. Therefore, the Environment Agency considers that information on the measured concentrations at the start and end of the test and details regarding the analytical method would be useful to support the quoted geometric mean measured endpoint.

No toxicity data are available for aquatic macrophytes, although this is not a standard REACH information requirement.

#### *Transformation products*

The EU REACH registration considers that PPVE hydrolyses with a half-life of 21.6 to 33.5 hours at 20 °C (Section 6.1.1.1), which would suggest that there could have been a significant loss of test concentration over 96 hours under static conditions. Five other toxicity studies with various species of algae and duckweed are noted in the PBT assessment section of the EU REACH PPVE registration dossier for PFPA. The lowest  $E_rC_{50}$  is reported to be 10.4 mg/L for *P. subcapitata* (green algae) and the lowest NOEC is 3.45 mg/L for the same species. The EU REACH registration considers that *P. subcapitata* is the most sensitive species to PFPA over all other aquatic species evaluated. No additional information on the methods or endpoints for these tests are currently available. Overall, the data indicate that PFPA has a low short- and long-term toxicity to algae.

#### **7.1.4 Sediment organisms**

No relevant information is available in the EU REACH registration dossier.

#### **7.1.5 Other aquatic organisms**

No other relevant information is available.

## 7.2 Terrestrial compartment

No relevant information is available in the EU REACH registration dossier.

## 7.3 Microbiological activity in sewage treatment systems

**Table 7.4 Summary of toxicity to sewage microorganisms**

Method	Analytical method	Results	Reliability	Reference
<b>OECD TG 209 (static)</b>	N/A	Combined limit/range-finding test 3-h EC <sub>50</sub> >1 000 mg/L (nominal); inhibition of total respiration 3-h NOEC ≥1 000 mg/L (nominal); inhibition of total respiration	Registrant: 2 (key study)	Unnamed, 2014, cited in ECHA (2020b)

Note: N/A – not applicable.

One Activated Sludge Respiration Inhibition Test (ASRIT) is included in the EU REACH registration dossier as the key study (Unnamed, 2014, cited in ECHA, 2020b). This sewage treatment microorganism toxicity study was performed according to OECD TG 209 and GLP. The test was conducted using PPVE with an analytical purity of 98.5% (w/w) and 1.5 g/L of activated sludge obtained from a sewage treatment plant receiving predominantly domestic sewage.

The test was described as a combined limit/range-finding test, and conducted using loading rates of 10 (1 replicate), 100 (1 replicate) and 1 000 mg/L (3 replicates), together with 6 replicates for the blank control. The EU REACH registration states that the test substance was not completely soluble in the test medium at these loading rates. The test concentrations and levels of replication used are in line with recommendations for OECD TG 209 range-finding tests. Nitrification controls, an abiotic control and a positive control with the reference substance 3,5-dichlorophenol were also run, although it is not clear whether these were all conducted in parallel with the above loading rates and blank control. Due to its volatility and low water solubility the test substance was added directly to the test vessels. An open test system was used with continuous aeration and stirring throughout the exposure to obtain optimal contact between the test substance and the test organisms.

No statistically significant effect on total respiration rate was observed and therefore, the 3-h NOEC was ≥1 000 mg/L and the 3-h EC<sub>50</sub> was >1 000 mg/L based on nominal concentrations. Oxygen consumption at 1 000 mg/L of the test substance with the nitrification inhibitor ranged from -8 to 3% inhibition relative to the nitrification control, suggesting that there was little to no effect on heterotrophic respiration. The abiotic control also indicated that abiotic oxygen uptake via oxidation does not occur with this substance.

The EU REACH registration considers that this study is reliable with restrictions (Klimisch 2) because an open test system was used although the test substance is volatile.

The Environment Agency expects that the loss of the test substance could have been significant even though the test duration was relatively short (3 hours), due to the use of an open and aerated test system and the high potential for the substance to volatilise (Section 6.2.2). No modifications to the aeration regime were made to minimise these losses contrary to OECD TG 209. In addition, the nominal test concentrations were significantly in excess of the water solubility (Section 5.3). Analytical support data are recommended for volatile and poorly water soluble test substances to confirm the exposure concentrations. However, the Environment Agency notes that the direct addition of the test substance to the test system meant that no chemical analysis of the test solutions could be carried out.

The range of pH values from 7.3-8.2 was slightly higher than recommended in OECD TG 209 at  $7.5 \pm 0.5$  and the temperature was lower than the recommended  $20 \text{ °C} \pm 2 \text{ °C}$ , ranging from 15.9 to 19.5 °C. Despite these minor deviations to the test guideline, the  $EC_{50}$  based on sludge respiration in the positive control with 3,5-dichlorophenol was within the expected range and the validity criteria for the blank control oxygen uptake were met. The study was also well documented. The absence of inhibition of oxygen consumption by the test substance in this combined limit/range-finding test indicates that a definitive test is unnecessary.

Overall, the study indicates that the substance is not toxic to sewage microbes. Although there were minor deviations to the study parameters recommended by OECD TG 209, the Environment Agency considers that the study is sufficiently reliable for the purposes of this assessment given that the study validity criteria were met.

## 7.4 Atmospheric effects

The Henry's Law constant indicates that PPVE is likely to significantly partition to air (see Section 6.2.2). PPVE photodegrades in air, with a half-life of around 5 days, and PFFA and hydrofluoric acid (HF) are the ultimate degradation products (see Section 6.1.1). The EU REACH registration considers that neither PPVE nor any of its photodegradation products contribute to ozone depletion due to the fast quenching of fluorine radicals by water or hydrogen donors to form HF, slow reaction of fluorine oxide (FO) radicals with oxygen and the obligatory reformation of fluorine radicals in the pathway. After quenching as HF, the EU REACH registration states that fluorine radicals are rapidly and irreversibly removed.

No data about biotic effects (e.g. to plants) from aerial exposure are available.

No information has been provided on the global warming potential of PPVE. However, despite the fact that it is expected to be present in the atmosphere following release (see



Section 6.2.3), the relatively short half-life in air (compared with perfluorocarbons) suggests that its global warming potential will be low (see Section 9.5).

## 8 Mammalian toxicology

The following information is taken directly from the ECHA public dissemination website entry for PPVE (ECHA, 2020b). The focus is on those mammalian endpoints which are potentially relevant for determination of the substance as Toxic ('T') according to the REACH Annex 13 criteria (see Section 9.3) or for a wildlife secondary poisoning assessment (see Section 9.6). No human health hazard assessment has been undertaken. The study details and their reliability (Klimisch) scores are as presented in the EU REACH registration and the Environment Agency has not evaluated this information.

### 8.1 Toxicokinetics

No information on the toxicokinetics is available in the EU REACH registration dossier.

### 8.2 Repeated dose toxicity

**Table 8.1 Summary of mammalian repeated dose toxicity endpoints**

Method	Species	Brief study details	Results	Reliability (Klimisch) score	Reference
<b>Combined repeated dose toxicity study and reproduction/developmental toxicity screening test, OECD TG 422 GLP</b>	Rat	Administered via inhalation at measured concentrations of 0, 3.26, 10.92 and 43.89 mg/L in air for 28 days in males, 50-53 days in females that delivered and 35-38 days in females that failed to deliver offspring.	NOAEC $\geq$ 43.89 mg/L air (measured). No adverse treatment-related effects on mortality, clinical signs, body weight and body weight gain, organ weights, food consumption, haematology, clinical biochemistry, behaviour, gross pathology and histopathology were observed.	Registrant: 1 (key study)	Unnamed (2017) cited in ECHA (2020b)

Method	Species	Brief study details	Results	Reliability (Klimisch) score	Reference
<b>Non-guideline study</b> <b>Non-GLP</b>	Rat	Administered via inhalation at measured concentrations of 0, 27.2 and 54.4 mg/L air test article for 6 hours a day, 5 days a week for 3 weeks.	NOAEL $\geq$ 54.4 mg/L air (measured). No adverse treatment-related effects on mortality, body weight and body weight gain, haematology, clinical biochemistry, urinalysis, gross pathology and histopathology were observed. Rats exposed to 54.4 mg/L air of the test article had slight irritation to the eyes and nose, signs of CNS depression, reduced body weight gain and reduced food consumption compared to the control.	Registrant: 2 (supporting study)	Unnamed (1976) cited in ECHA (2020b)

### 8.3 Mutagenicity

Three *in vitro* genetic toxicity studies are included in the EU REACH registration dossier.

**Table 8.2 Summary of mutagenicity endpoints**

Method	Species	Brief study details	Results	Reliability	Reference
<b>Bacterial Reverse Mutation Assay, OECD TG 471 421 + US EPA 40 CFR 798.5265 GLP</b>	<i>Salmonella typhimurium</i> and <i>Escherichia coli</i> strains	Exposure at 0.1, 0.2, 0.3, 0.4 and 0.5%, both in absence and presence of metabolic activation.	Negative (no adverse effects reported at these concentrations).  The test article is not mutagenic with or without metabolic activation under the test conditions.	Registrant: 1 (key study)	Unnamed (1994) cited in ECHA (2020b)
<b>Mammalian Chromosome Aberration Test, OECD TG 473 + US EPA OTS 798.5375 GLP</b>	Human lymphocytes	Exposure of cell plates at 0.1, 0.25, 0.4 and 0.5% in trial one and 0.05, 0.3, 0.35 and 0.5% in trial two, both in the absence of metabolic activation.	Negative (no adverse effects reported at these concentrations).  The test item is not clastogenic in human lymphocytes.	Registrant: 1 (key study)	Unnamed (1994) cited in ECHA (2020b)
<b>Mammalian Cell Gene Mutation Test, OECD TG 476 + US EPA OPPTS 870.5300 GLP</b>	Chinese hamster ovary	Exposure of cell plates at 0.1, 0.2, 0.3, 0.4 and 0.5% in the presence and absence of metabolic activation.	Negative (no adverse effects reported at these concentrations).  Under the study conditions, the test substance is not mutagenic at the HPRT locus in Chinese hamster ovary V79 cells with or without metabolic activation.	Registrant: 1 (key study)	Unnamed (1994) cited in ECHA (2020b)

## 8.4 Carcinogenicity

No information on the carcinogenicity is available in the EU REACH registration dossier.

## 8.5 Toxicity to reproduction (effects on fertility and developmental toxicity)

Table 8.3 Summary of mammalian reproductive toxicity endpoints

Method	Species	Brief study details	Results	Reliability	Reference
<b>Combined repeated dose toxicity study and reproduction/developmental toxicity screening test, OECD TG 422 GLP</b>	Rat	Administered via inhalation at measured concentrations of 0, 3.26, 10.92 and 43.89 mg/L in air for 28 days in males, 50-53 days in females that delivered and 35-38 days in females that failed to deliver offspring.	NOAEC $\geq$ 43.89 mg/L air (measured); based on parental systemic toxicity, reproduction and development.  No adverse treatment-related effects on mortality, clinical signs, body weight and body weight gain, organ weights, food consumption, haematology, clinical biochemistry, behaviour, gross pathology and histopathology were observed.	Registrant: 1 (key study)	Unnamed (2017) cited in ECHA (2020b)

## 8.6 Summary of mammalian toxicology

Based on the available mammalian toxicology data, the EU REACH registration proposes an inhalation DNEL (Derived No Effect Level) for workers of 294 mg/m<sup>3</sup> air based on the most sensitive repeated dose toxicity endpoint with an overall assessment factor (AF) of 75. A dermal DNEL for workers of 82 mg/kg bw/day is also proposed based on the most sensitive repeated dose toxicity endpoint with an overall AF of 300.

No self-classifications for reproductive toxicity, mutagenicity or carcinogenicity are proposed (Section 9.1).

# 9 Environmental hazard assessment

## 9.1 Classification and labelling

### 9.1.1 Harmonised classification

PPVE does not have a harmonised classification under the EU Classification, Labelling and Packaging (CLP) Regulation ((EC) No 1272/2008), nor a mandatory classification under UK CLP.

### 9.1.2 Self-classification

The EU REACH registration propose the following hazard warning:

- Eye Irrit. 2 (H319)

ECHA's Classification and Labelling (C&L) Inventory aggregated self-classifications include the above hazard class and additional hazard classes as listed below (ECHA, 2020d).

- Flam. Liq. 1 (H224)
- Acute Tox. 4 (H302)
- Skin Irrit. 2 (H315)
- STOT SE 3 (H335)
- Acute Tox. 4 (H312)
- Acute Tox. 4 (H332)

### 9.1.3 Conclusions for classification and labelling

PPVE is not readily biodegradable (see Section 6.1). The EU REACH registration considers that the available hydrolysis study indicates that the substance is rapidly hydrolysed to PFPA with half-lives of 29.2 to 43.4 hours at 10 °C and pH 4, 7 and 9. The transformation product PFPA is likely to be not rapidly degradable and not bioaccumulative in aquatic organisms. The available aquatic ecotoxicity data reported by the EU REACH registration indicate effects above 1 mg/L, and do not meet the criteria for environmental hazard classification. PPVE would therefore meet the rapid degradability criterion for abiotic degradation of 16 days. However, the Environment Agency considers that further information is required to confirm the hydrolysis of PPVE before a decision can be taken about its relevance. The Environment Agency therefore currently considers that PPVE is "not rapidly degradable" for the purposes of hazard classification.

The log K<sub>ow</sub> of 4 (see Section 5.4) means that PPVE meets the bioaccumulation criterion for the purposes of hazard classification under CLP. Further information to clarify the

behaviour of PPVE in water is required before a final evaluation of its aquatic bioaccumulation potential can be finalised.

Acute ecotoxicity endpoints are available for fish, invertebrates and algae (see Section 7). The Environment Agency has not been able to independently assess the studies for reliability, but they are considered reliable in the EU REACH registration. Since all acute L/EC<sub>50</sub> values exceed the practical limit of water solubility, **Aquatic Acute classification is not required**. This is consistent with the UK supplier's view.

Chronic aquatic toxicity data for PPVE are not available for fish or aquatic invertebrates. A 72-h ErC<sub>10</sub> of >0.458 mg/L is available for algae, which does not meet the criteria for an Aquatic Chronic classification because it is above the practical limit of water solubility. The surrogate approach for this non-rapidly degradable substance using the acute toxicity endpoints for fish and invertebrates also results in no Aquatic Chronic classification because these are all above the practical limit of water solubility. However, the lack of rapid degradability (pending further information about hydrolysis) and a bioaccumulation potential indicated by a log K<sub>ow</sub> ≥4, means that an **Aquatic Chronic 4** ('safety net') **classification is applicable** in the absence of information on long-term toxicity to fish and invertebrates. This is not consistent with the UK supplier's view that an Aquatic Chronic classification is unnecessary.

The human health hazard classification has not been considered.

## 9.2 Assessment of endocrine disrupting (ED) properties

Not evaluated. The ecotoxicity dataset does not include any studies that assess ED potential and no additional information was identified during the literature search.

## 9.3 PBT and vPvB assessment

Persistence: No environmental half-life data are available for comparison with the definitive criteria in REACH Annex 13. PPVE is not readily biodegradable and although the EU REACH registration considers that it degrades significantly via hydrolysis, the Environment Agency considers that this requires confirmation (see Section 6.1). It therefore meets the screening criterion for being potentially persistent (P) or very persistent (vP). The EU REACH registration dossier has the same conclusion.

Bioaccumulation: The log K<sub>ow</sub> of 4 (see Section 5.4) means that PPVE does not meet the screening bioaccumulation ('B') criterion of a log K<sub>ow</sub> above 4.5 under REACH (ECHA, 2017d).

In terms of bioaccumulation in air breathing organisms, the screening criteria are log K<sub>ow</sub> > 2 and log K<sub>oa</sub> > 5. The log K<sub>ow</sub> exceeds the threshold but the log K<sub>oa</sub> does not.



There is some uncertainty in the log  $K_{OA}$  value, but this criterion does not appear to be met based on the available information. The bioaccumulation potential of PPVE in air-breathing organisms is uncertain but there are no indications of concern based on currently available data

The EU registration dossier considers that PPVE does not fulfil the criteria for 'B' based on the log  $K_{OW}$  and log  $K_{OA}$ .

Toxicity: In terms of aquatic toxicity (see Section 7), a 72-h  $E_rC_{10}$  of >0.458 mg/L is available for algae, which does not meet the REACH Annex 13 criterion for toxicity (T) of <0.01 mg/L.

Since all acute  $L/EC_{50}$  values exceed the practical limit of water solubility, PPVE does not meet the screening criterion for being potentially T based on toxicity to aquatic organisms. There are no chronic aquatic toxicity data for fish or aquatic invertebrates.

PPVE does not meet the T criterion based on mammalian toxicity as indicated by the self-classifications for human health presented in the EU REACH registration dossier and C&L Inventory (see Section 8). The EU REACH registration dossier has the same conclusion.

No information is available on the ED potential.

Overall conclusion: PPVE screens as potentially P/vP. It does not currently screen as B. It does not screen as T based on the available aquatic and mammalian toxicity data, but there are no chronic aquatic toxicity data for fish or aquatic invertebrates.

By analogy with perfluorohexanoic acid (PFHxA), the transformation product PFPA is not expected to meet the PBT or vPvB criteria (ECHA, 2020c), although it is expected to be very persistent.

The EU REACH registration concludes that PPVE is not PBT or vPvB. Based on the available information, the Environment Agency agrees.

## 9.4 Groundwater hazard

Draft persistence, mobility and toxicity (PMT) criteria have been developed by the German Federal Environment Agency as intrinsic hazard criteria to identify substances that are difficult to remove during normal wastewater treatment practices and may be a threat to remote aquatic environments and drinking water sources, including groundwater (Arp and Hale, 2019). The criteria for P and vP are consistent with those in REACH Annex 13, whereas the mobile criterion is unique to PMT assessments. The T criteria include those in REACH Annex 13, in addition to considerations for carcinogenicity, effects via lactation, long-term toxicity to the general human population and endocrine disruption potential.

There is no legal basis for these criteria under the UK REACH Regulation, but for completeness, a brief evaluation is included here.

Persistence: PPVE meets the screening criterion for being potentially P or vP (see Section 9.3).

Mobility: An experimental log  $K_{oc}$  value is not available but predicted log  $K_{oc}$  values are in the region of 3.3 (see Section 6.2.1). There is significant uncertainty in such predictions for highly fluorinated substances. PPVE therefore meets the draft criterion as being mobile (M) ( $\log K_{oc} \leq 4$ ), but a definitive log  $K_{oc}$  measurement would provide clarity about whether the vM ( $\log K_{oc} \leq 3$ ) criterion is met.

Toxicity: PPVE does not meet the draft T criterion based on mammalian toxicity as indicated by the self-classifications for human health presented in the EU REACH registration dossier and C&L Inventory (see Section 9.1). No information is available on the ED potential.

PPVE does not meet the draft T criterion based on the available ecotoxicity information, although no chronic aquatic toxicity data for fish or aquatic invertebrates are available.

Overall conclusion: PPVE screens as potentially P/vP and is likely to be M but there is insufficient information to conclude whether it meets the draft T criterion. PPVE does not meet the draft vPvM criteria based on existing information, although there is uncertainty in the data used for the mobility criterion and a reliable measurement could lead to a reassessment since vPvM cannot be excluded. PPVE is a volatile liquid, and the influence of volatility is not considered under the criteria.

By analogy with PFHxA, the transformation product PFPA is expected to be vPvM. Further evaluation of these properties has not been considered for the purposes of this report.

## 9.5 Greenhouse gas hazard

Many fluorinated gases have very high global warming potentials (GWPs) relative to other greenhouse gases, so small atmospheric concentrations can have disproportionately large effects on global temperatures (US EPA, 2020b).

The GWP is defined by the Intergovernmental Panel on Climate Change (IPCC, 2014) as *“an index measuring the radiative forcing following an emission of a unit mass of a given substance, accumulated over a chosen time horizon, relative to that of the reference substance, carbon dioxide (CO<sub>2</sub>). The GWP thus represents the combined effect of the differing times these substances remain in the atmosphere and their effectiveness in causing radiative forcing.”*

In 2010, fluorinated gases covered under the Kyoto Protocol (F-gases) accounted for 2% of total anthropogenic greenhouse gas emissions (IPCC, 2014). PPVE did not contribute to this.

PPVE is not covered under the Kyoto Protocol and related UK Regulations for F-gases (EC, 2014; Coffey, 2019). Although volatile, it degrades rapidly in air. Therefore, the

Environment Agency considers there are no concerns for greenhouse gas effects from the substance.

## 9.6 Limit values

### 9.6.1 Predicted No Effect Concentration (PNEC) derivation

A PNEC is an indication of an acceptable environmental concentration based on evidence from toxicity studies. Available hazard data are discussed in Sections 7 and 8. No significant adverse effects have been observed in the available aquatic ecotoxicity studies up to around the limit of water solubility. Long-term data for fish and invertebrates are not available.

The PNECs in the EU REACH registration are presented in Table 9.1. PNECs have also been derived by the Environment Agency following REACH guidance (ECHA, 2008) and the EUSES model (ECHA, 2019). The values are presented in Table 9.2 and are based on the endpoints that are considered reliable in the EU REACH registration. Note: Although PNECs have been derived, they are “greater than values”.

**Table 9.1 PNECs derived for PPVE in the EU REACH registration (ECHA, 2020b)**

Protection goal	PNEC	Notes
<b>Fresh surface water</b>	0 mg/L	The Environment Agency notes that the ECHA portal has rounded the PNEC value to 0 mg/L
<b>Freshwater sediment</b>	0.102 mg/kg sediment dw	Equilibrium partitioning method (EPM)
<b>Sewage treatment micro-organisms</b>	100 mg/L	
<b>Marine surface water</b>	0 mg/L	The Environment Agency notes that the ECHA portal has rounded the PNEC value to 0 mg/L
<b>Marine sediment</b>	0.01 mg/kg sediment dw	EPM
<b>Soil</b>	0.012 mg/kg soil dw	EPM
<b>Secondary poisoning in freshwater food chains</b>	No potential for bioaccumulation	

**Table 9.2 PNECs derived for PPVE by the Environment Agency**

<b>Protection goal</b>	<b>Most sensitive toxicity descriptor</b>	<b>Assessment factor</b>	<b>PNEC</b>	<b>Justification/ remarks</b>
<b>Fresh surface water</b>	72-h ErC <sub>50</sub> >0.458 mg/L for algae	1 000	>0.00046 mg/L	No chronic toxicity endpoints available for fish or invertebrates
<b>Freshwater sediment</b>			>0.022 mg/kg wet weight	EUSES calculation (EPM)
<b>Sewage treatment micro-organisms</b>	3-h NOEC ≥1000 mg/L	10	≥100 mg/L	Sludge respiration NOEC available
<b>Marine surface water</b>	72-h ErC <sub>50</sub> >0.458 mg/L for algae	10 000	>0.000046 mg/L	No chronic toxicity endpoints available for fish or invertebrates and no data for additional taxonomic groups
<b>Marine sediment</b>			>0.0022 mg/kg wet weight	EUSES calculation (EPM)
<b>Soil</b>			>0.20 mg/kg wet weight	EUSES calculation (EPM)
<b>Secondary poisoning</b>			N/A	No toxicity studies on dietary or oral exposure are available

It should be noted that no adverse effects have been observed in the available ecotoxicity studies up to the apparent limit of solubility in the test media. The PNECs are therefore “greater than” values, and precautionary.

## 9.6.2 Qualitative/semi-quantitative descriptors for other critical hazards

PPVE transforms in the environment to PFFPA, which is expected to be a vPvM substance. The risk management for approach for PMT/vPvM substances has not yet been established in the UK.

# 10 Exposure assessment

## 10.1 Environment

### 10.1.1 Environmental releases

In the EU, PPVE has been registered by 10 companies in the overall tonnage band 100 to 1 000 tonnes/year for both manufacture and import. The Lead EU REACH Registrant is based in the EU. There is an exposure assessment in the joint registration CSR, which covers manufacture and polymerisation. The following assessment for polymer manufacturing is based on the import volume used by the UK supplier, AGC Chemicals Europe Ltd.

### 10.1.2 Short description of exposure scenarios and measures for reducing emissions to the environment

PPVE is imported by AGC Chemicals Europe Ltd for use as a co-monomer.

Life cycle stages stated in the EU REACH registration dossier are:

- Manufacture of the substance [this does not apply in the UK];
- Formulation into a mixture;
  - Formulation, transfer, (re-)filling and laboratory reagent;
- Use as a monomer in polymerisation;
  - Manufacture of plastic products including compounding and conversion
  - Manufacture of fine chemicals

#### Polymer manufacture

AGC Chemicals Europe Ltd has provided details of the on-site production process, including the following non-confidential summary. Tetrafluoroethylene is transferred into the reactor and PPVE is dosed directly from the drums it is delivered in. The reaction is done at elevated temperature and pressure, to produce fluoropolymers. PPVE is in the form of a gas during this reaction. When the batch is complete, the pressure in the reactor

is reduced and all the remaining gaseous monomers are transferred into the gas holder. The company has confirmed that there is a maximum release to air of <1 kg PPVE per year from this part of the process (further details are confidential).

Due to the toxicity of other constituents of the waste there are stringent regulatory controls under separate legislation to ensure that there are no releases to the environment once the waste has been transferred into the gas holder. There are no other emissions from the process.

The sole waste stream is transferred to either on-site or off-site incineration. The on-site incinerator is governed by the decision document for the environmental permit variation issued in July 2017 (ref: EPR/BU5453IY) under the Environmental Permitting (England and Wales) Regulations 2016. It is not currently operating, and so all waste is sent off-site for high temperature incineration.

As the releases from AGC Chemicals Europe Ltd polymerisation process are below 1 kg/year and the waste produced from the process is fully contained prior to high temperature incineration, the Environment Agency considers that there is no need for a quantitative exposure assessment.

There are no other fluoropolymer manufacturing sites in the UK (personal communication with AGC Chemicals Europe Ltd).

### **Polymer use**

As described in Section 3, the copolymer product produced by AGC Chemicals Europe Ltd is sold to downstream users and used for wire coatings, cables and tubing in the semiconductor industry, and cable insulation in the automotive and aerospace industry. AGC Chemicals Europe Ltd indicate that there are theoretically trace amounts of residual PPVE in the copolymer product. Details are confidential. The total amount that would potentially be available for release is in the order of grams per year.

Since fluoropolymers produced or imported into the EU could be supplied to the UK market, the Environment Agency has also considered potential emissions from imported polymers. The CSR undertaken by the Lead EU Registrant did not include any downstream user life cycle stages. The quantity of unreacted PPVE in such polymers would be below 100 kg/year based on the concentration data supplied by AGC Chemicals Europe Ltd and the maximum theoretical level of supply at the current EU REACH registered tonnage band (999 tonnes/year). This assumes that other producers follow similar procedures to remove PPVE (which may not be the case), but on the other hand, total EU supply is likely to be below 999 tonnes/year. In addition, the level of UK supply from these sources will be a fraction of this (e.g. around 10%). The amount of PPVE in polymers imported into the UK will therefore be below 10 kg/year. Further information is confidential.

Fluoropolymers made from PPVE can be thermally processed to make finished articles. Given the volatility of PPVE it is possible that there will be some emissions to air during polymer processing. Distribution modelling suggests that most of the PPVE released to air will remain there, where it will photodegrade (see Sections 6.2 and 6.1.1).

The Environment Agency considers this life cycle stage to be a low priority for quantitative exposure assessment.

## **Waste stages (EU Registrants)**

The CSR undertaken by the Lead EU Registrant did not include any waste life cycle stages and therefore there are no release estimates for this stage. Given the likely low quantities of PPVE in any polymer at the end of its service life, the Environment Agency considers this life cycle stage to be a low priority for further evaluation.

### **10.1.3 Monitoring data**

No monitoring data were identified in the EU REACH registration dossier, academic literature or internal Environment Agency monitoring network. The environmental permit has no requirement to monitor for PPVE.



# 11 Risk characterisation

Environmental releases from the UK manufacturing site are below 1 kg/year to air. A reasonable worst-case estimate is that the residual PPVE content in polymers on the UK market (from all suppliers) will be lower than 10 kg/year.

No significant adverse effects have been observed in the available aquatic ecotoxicity studies up to the limit of solubility in the test media. Long-term data for fish and invertebrates are not available. Although PNECs have been derived, they are “greater than values”. The substance does not meet the PBT/vPvB or draft PMT/vPvM criteria and no information is available about endocrine disruption. However, there is uncertainty in the data used for the mobility criterion and a reliable measurement could lead to a reassessment.

On the basis of low releases and lack of significant adverse effects in the information currently available, the Environment Agency considers that the direct risk to the environment from PPVE is likely to be low.

According to the UK importer, PPVE is a source of PFPA in small amounts in the environment. PFPA is expected to have vPvM properties, so it may distribute widely in the environment, and be difficult to remove from water. A full hazard identification has not been performed for the purposes of this evaluation. However, any risk management required for PFPA in future should take account of the relative contributions from all sources, including PPVE.

# 12 Conclusion and recommendations

## 12.1 Conclusion

PPVE is a PFAS that belongs to the group of per-/polyfluorinated vinyl ethers. It is imported to the UK and used in the manufacture of fluoropolymers at a single site. A low level of release occurs to air during the manufacture of fluoropolymers at this site. Small releases may also occur at polymer processing sites and from articles in use.

Based on the available hazard data the following conclusions can be reached:

- It is precautionary to conclude that PPVE meets the criteria to be classified as Aquatic Chronic 4 for aquatic environmental hazard under the CLP Regulation; further clarification of the potential for hydrolysis may modify this conclusion.
- PPVE is not readily biodegradable, although it is expected to degrade in air. PPVE therefore screens as potentially persistent or very persistent, although the UK importer considers that it hydrolyses to PFPA. Based on evidence from related substances, PFPA is likely to be extremely persistent.
- The log  $K_{OW}$  and log  $K_{OA}$  of PPVE indicate that bioconcentration in fish and bioaccumulation in air-breathing organisms are unlikely to be high, although there is some uncertainty in the log  $K_{OA}$  value.
- PPVE does not meet the toxicity criterion of REACH Annex 13.
- In summary, PPVE screens as potentially P/vP, but is unlikely to be B or T.
- PPVE screens as P/vP and M but there is insufficient information to conclude whether it meets the T criterion. There is uncertainty in the data used for the mobility criterion and a reliable measurement could lead to a reassessment of vM. It might pose a concern regarding the contamination of groundwaters, although the influence of volatility is not considered in this assessment. PPVE is, however, a source of PFPA in the environment due to degradation processes, and PFPA is expected to be vPvM.
- On the basis of low releases and lack of significant adverse effects according to the information currently available, the Environment Agency considers that the direct risk to the environment from PPVE is likely to be low. Any risk management required for PFPA in future should take account of the relative contributions from all sources, including PPVE.

## 12.2 Recommendations

### 12.2.1 Recommendations to the UK supplier

Although this evaluation is not a formal assessment under UK REACH, the Environment Agency proposes several ways to improve the data package to allow a more robust assessment of the hazards and risks posed by PPVE, including:

- Details of whether the water solubility study took steps to minimise colloid formation and volatilisation; the influence of hydrolysis also needs to be considered if this is confirmed as a relevant degradation pathway.
- Details of the influence of hydrolysis on the log K<sub>OW</sub> study if this is confirmed as a relevant degradation pathway.
- Details of how the log K<sub>OA</sub> value was generated.
- A re-evaluation of the hydrolysis study to allow its reliability to be determined, and if necessary a new study conducted using radiolabelled test material to provide a mass balance of the test system.
- A new experimental log K<sub>OC</sub> study, subject to confirmation of lack of hydrolysis.
- Updated distribution modelling for release to different compartments, using updated and justified physico-chemical and half-life value input parameters.
- Updates to the robust study summaries for the available aquatic toxicity studies to include information on the initial and end measured concentrations.
- A self-classification of Aquatic Chronic 4 for aquatic environmental hazard under the CLP Regulation, subject to confirmation of lack of hydrolysis.

### **12.2.2 General regulatory recommendations for consideration by relevant UK authorities**

The Environment Agency along with HSE have been undertaking a Regulatory Management Options Analysis (RMOA) for PFAS, and the information summarised in this evaluation has fed into that analysis to identify the most appropriate risk management measures for PFAS in a UK context.

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## 14 List of abbreviations

BCF	bioconcentration factor
CAS	Chemical Abstracts Service
C&L	Classification and Labelling [Inventory]
CLP	Classification, Labelling and Packaging [Regulation]
ECHA	European Chemicals Agency
GC/MS	gas chromatography/mass spectrometry
InChI	IUPAC International Chemical Identifier
IUPAC	International Union for Pure and Applied Chemistry
LFER	Linear Free Energy Relationship
MLFER	Molecular linear free energy relationship
OECD	Organisation for Economic Co-operation and Development
OSPAR	Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic
PACT	Public Activities Co-ordination Tool
PBT	persistent, bioaccumulative and toxic
PFAS	per- and polyfluorinated alkyl substances
PFHxA	perfluorohexanoic acid
PFOS	perfluorooctane sulfonic acid
PFPA	perfluoropropionic acid
PMT	persistent, mobile and toxic
POP	persistent organic pollutant
PTFE	polytetrafluoroethylene
REACH	Registration, Evaluation, Authorisation and restriction of Chemicals [Regulation]
RMOA	Risk Management Option Analysis [REACH]

SMILES	Simplified Molecular Input Line Entry System
USEPA	US Environmental Protection Agency
vPvB	very persistent, very bioaccumulative
vPvM	very persistent, very mobile

## Appendix A: Literature search

A literature search was undertaken by the Environment Agency on the 2<sup>nd</sup> April 2020 to identify published information relevant to the assessment of PPVE. The keywords listed in Table A.1 were searched for in PubMed (<https://pubmed.ncbi.nlm.nih.gov/>) and Science Direct (<https://www.sciencedirect.com/>). In order to maximise the number of records identified keywords were based on the substance name only, and not on the endpoints of interest or year of publication.

**Table A.1 Literature search terms and number of hits**

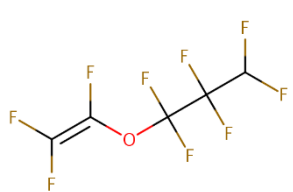
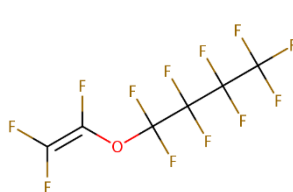
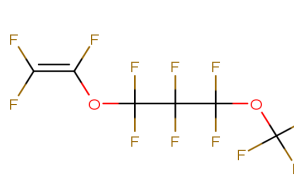
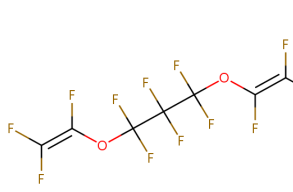
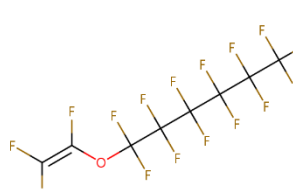
Search terms	PubMed	Science Direct
1623-05-8	0	7
1,1,1,2,2,3,3-Heptafluoro-3-[(trifluorovinyl)oxy]propane	0	1
Perfluoro propyl vinyl ether	3	61
PPVE	9	181
<b>Total unique records</b>	12	221

The identified records were screened manually for relevance to this assessment based on the title and abstract. Articles identified as of potential interest were obtained and reviewed for relevance. Those that were found to be relevant are discussed in the appropriate sections of this report.

## Appendix B: Additional analogues of PPVE

The US EPA CompTox Chemicals database (US EPA, 2021a; accessed February 2021) was used to identify relevant structures.

**Table B.1 Structural identifiers for additional analogues of PPVE**

Public name	1,1,2,2,3,3-Hexafluoro-1-((trifluorovinyl)oxy)propane	1,1,1,2,2,3,3,4,4-Nonafluoro-4-[(trifluoroethenyl)oxy]butane	1,1,2,2,3,3-Hexafluoro-1-[(trifluoroethenyl)oxy]-3-(trifluoromethoxy)propane	1,1,2,2,3,3-Hexafluoro-1,3-bis((trifluorovinyl)oxy)propane	1,1,1,2,2,3,3,4,4,5,5,6,6-Tridecafluoro-6-[(trifluoroethenyl)oxy]hexane
CAS number	84145-18-6	13782-76-8	40573-09-9	13846-22-5	103489-99-2
EC number	282-242-9	-	442-390-9	13846-22-5	-
Structural formula					
Molecular formula	C <sub>5</sub> HF <sub>9</sub> O	C <sub>6</sub> F <sub>12</sub> O	C <sub>6</sub> F <sub>12</sub> O <sub>2</sub>	C <sub>7</sub> F <sub>12</sub> O <sub>2</sub>	C <sub>8</sub> F <sub>16</sub> O

<b>Molecular weight</b>	248.048 g/mol	316.046 g/mol	332.045 g/mol	344.056 g/mol	416.061 g/mol
<b>SMILES code</b>	<chem>FC(F)C(F)(F)C(F)(F)OC(F)=C(F)F</chem>	<chem>FC(F)=C(F)OC(F)(F)C(F)(F)C(F)(F)C(F)(F)F</chem>	<chem>FC(F)=C(F)OC(F)(F)C(F)(F)C(F)(F)OC(F)(F)F</chem>	<chem>FC(F)=C(F)OC(F)(F)C(F)(F)C(F)(F)OC(F)=C(F)F</chem>	<chem>FC(F)=C(F)OC(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)F</chem>
<b>Source</b>	US EPA (2021b)	US EPA (2021c)	US EPA (2021d)	US EPA (2021e)	US EPA (2021f)

## Appendix C: QSAR models

Two main databases were used to source in silico data for this evaluation when required. These were the United States Environmental Protection Agency (US EPA) CompTox Dashboard (US EPA, 2020a) and the Royal Society of Chemistry (RSC) ChemSpider portal (RSC, 2020). Both integrate diverse types of relevant domain data through a cheminformatics platform, and are built upon a database of curated substance properties linked to chemical structures (Williams *et al.*, 2017).

The QSAR models available from these two platforms are presented in Table C.1 (data from other open access models are available in the CompTox dashboard, but for the sake of brevity, these have not been used for the purposes of this evaluation).

Table C.1 QSAR model outline

Name	Brief description
<b>ACD/Labs</b>	Predicts physicochemical properties via the <a href="#">Percepta Platform</a> <sup>2</sup> .
<b>EPISuite™ Estimation Programs Interface Suite™ for Microsoft® Windows</b>	A Windows®-based suite of physical/chemical, environmental fate and ecotoxicity property estimation programs developed by the US EPA and Syracuse Research Corp. It uses a single input (typically a SMILES string) to run the following estimation programs: AOPWIN™, AEROWIN™, BCFBAF™, BioHCwin, BIOWIN™, ECOSAR™, HENRYWIN™, HYDROWIN™, KOAWIN™, KOCWIN™, KOWWIN™, LEV3EPI™, MPBPWIN™, STPWIN™, WATERNT™, WSKOWWIN™ and WVOLWIN™.
<b>OPEn structure–activity/property Relationship App (OPERA)</b>	Open source suite of QSAR models providing predictions and additional information including applicability domain and accuracy assessment, as described in Williams <i>et al.</i> (2018). All models were built on curated data and standardized chemical structures as described in Williams <i>et al.</i> (2016). All OPERA properties are predicted under ambient conditions of 760 mmHg (103 kPa) at 25 °C.
<b>T.E.S.T. Toxicity Estimation Software Tool</b>	US EPA software application for estimating the toxicity of chemicals using QSAR methods. EPISuite™ is the model used to generate some physico-chemical data, although T.E.S.T. does not report K <sub>ow</sub> values and uses a different database for surface tension. (US EPA, 2016).

<sup>2</sup> <http://www.acdlabs.com/products/percepta/>

## EPISuite™

Table C.2 summarises the perfluorocarbons (PFCs) identified in the training / validation sets for EPISuite™. Applicability domain (US EPA, 2020c).

**Table C.2 EPISuite™ PFCs included in training and validation sets**

EPISuite model	Training set	Validation set
<b>MPBPVP v 1.42</b>	tetrafluoromethane hexafluoroethane tetrafluoroethylene octafluoropropane hexafluoropropene decafluorobutane perfluorocyclobutane perfluoro-n-hexane perfluorocyclohexane perfluoroheptane perfluoromethylcyclohexane	Not available
<b>WSKOWWIN v 1.41</b>	None identified	octafluoropropane octafluorocyclobutane
<b>Water solubility estimate from fragments (v 1.01 est)</b>	trifluoromethane	tetrafluoromethane hexafluoroethane octafluoropropane perfluorocyclobutane tetrafluoroethylene
<b>KOAWIN v 1.1</b>	Uses KOWWIN and HENRYWIN databases	
<b>KOCWIN v 1.66</b>	None identified	None identified
<b>KOWWIN v 1.67</b>	tetrafluoromethane hexafluoroethane	perfluorocyclohexane
<b>HENRYWIN v 3.1</b>	tetrafluoromethane hexafluoroethane tetrafluoroethene	octafluoropropane perfluorocyclobutane

## Open Structure-activity/property Relationship App (OPERA)

OPERA is a free and open-source/open-data suite of QSAR models providing predictions for physicochemical properties, environmental fate parameters, and toxicity endpoints.

Applicability domain (AD) (Williams *et al.*, 2017):

- If a chemical is considered outside the global AD and has a low local AD index (< 0.4), the prediction can be unreliable.
- If a chemical is considered outside the global AD but the local AD index is average (0.4–0.6), the query chemical is on the boundary of the training set but has quite similar neighbours (average reliability). If the local AD index is high (> 0.6), the prediction can be trusted.
- If a chemical is considered inside the global AD but the local AD index is average (0.4–0.6), the query chemical falls in a “gap” of the chemical space of the model but still falls within the boundaries of the training set and is surrounded with training chemicals. The prediction therefore should be considered with caution.
- If a chemical is considered inside the global AD and has a high local AD index (> 0.6), the prediction can be considered reliable.

## T.E.S.T. (Toxicity Estimation Software Tool)

Data sets used in T.E.S.T. (US EPA, 2016) for parameters reported at 25 °C:

- Surface tension: Dataset for 1 416 chemicals obtained from the data compilation of Jasper 1972;
- Water solubility: Dataset of 5 020 chemicals was compiled from the database in EPI Suite™. Chemicals with water solubility's exceeding 1,000,000 mg/L were omitted from the overall dataset;
- Vapour pressure: Dataset of 2 511 chemicals was compiled from the database in EPI Suite™.

T.E.S.T. displays structures for substances from the test and training sets that are closest to the substance where a predicted value is required. A comparison between the experimental and predicted value for the substances in the test and training sets provides a similarity coefficient. If the predicted values match the experimental values for similar chemicals in the test and training set (and the similar chemicals were predicted well), there is greater confidence in the predicted value for the substance under evaluation.



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