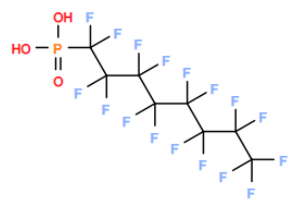
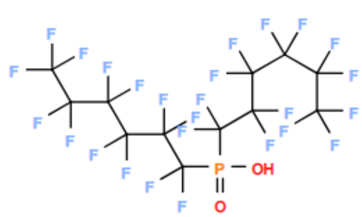
CAS #

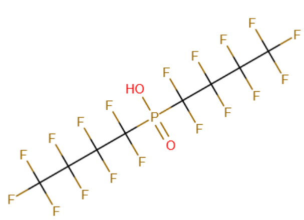
1. **1)** Perfluoroalkyl (C6-C12) Phosphonic acid: **68412-68-0** (C8 shown below)



2. **2)** Phosphinic Acid, bis (perfluoro-C6-12-alkyl) derivatives: **68412-69-1** (C6 shown below)



3. **3)** Bis(nonafluorobutyl) phosphinic acid: **52299-25-9**



NAMES OF EXAMPLE PERFLUOROALKYL PHOSPHONIC AND PHOSPHINIC ACIDS:

1) Perfluoro-C6-12-alkyl phosphonic acid
2) Phosphinic acid, bis(perfluoro-C6-12-alkyl) derivatives
3) bis(1,1,2,2,3,3,4,4,4-nonafluorobutyl)phosphinic acid

Synonym[1]s:
(68412-68-0): C6–12 PFPA, Perfluoro-C6-C12 ethyl hydrogen phosphate
(68412-69-1): Di-perfluoroalkyl (C6-C12) phosphinic acid, C6–12/C6–12 PFPIA
(52299-25-9): bis(1,1,2,2,3,3,4,4,4-nonafluorobutyl)phosphinic acid

RTECS #[2]: No data available

EINECS #[3]:
Phosphonic acid: 270-204-4
Phosphinic acid: 270-206-5
Bis(nonafluorobutyl) phosphonic acid: 700-183-3

Molecular Weight[4]:
500.05 g/mol (CAS#68412-68-0)
702.07 g/mol (CAS# 68412-69-1)
502.04 g/mol (CAS# 52299-25-9)

Molecular Formula[5]:
$C_8H_2F_{17}O_3P$ (CAS# 68412-68-0)
$C_{12}HF_{26}O_2P$ (CAS# 68412-69-1)
$C_8HF_{18}O_2P$ (CAS# 52299-25-9)

Related CAS #'s:
90481-10-0; 93062-53-4; 70609-44-8; 610800-34-5; 500776-69-2

PHYSICAL CHARACTERISTICS	
Primary Use	**Industrial use:** Surface active agent in soap, cleaning compounds, fertilizers, and other agricultural chemicals. (Phosphonic acid 68412-68-0).[6]

	Consumer use: Cleaning and furnishing care products, leveling and wetting agent, and defoaming agent in pesticides. (Phosphonic acid 68412-68-0). [7] **Commercial use:** Cleaning and furnishing care products. (Phosphonic acid 68412-68-0). [8] "Mixtures of PFPAs and PFPIAs with chains of six to 12 per fluorinated carbon atoms are foam-dampening agents with a range of potential applications, including in the textile industry for textile finishing procedures (Heid, et al., 1975).[9] These substances were produced in moderate volumes in the USA (4.5 to 226.8 tonnes annually) based on historical production volume information from 1998 and 2002 (Howard and Muir, 2010).[10] Analysis of publicly accessible records from Sweden, Denmark and Norway by (Wang, et al., 2016) indicates that a minimum of 4.33 tonnes of C6–12 PFPA and 3.33 tonnes of C6–12/C6–12 PFPIA were used in the period between 1999 and 2011.[11] The aluminum salts of C6–C12 PFPA and C6–C12/C6–C12 PFPIA (CAS RNs 90481-10-0 and 93062-53-4) are potential direct precursors to PFAAs derived from the substances in this group. However, these two aluminum salts are not listed on the Australian Inventory of Chemical Substances and they are, therefore, assumed not to be in use in Australia (OECD, 2007)."[12]
Physical state, odor at room temperature & pressure	(68412-68-0; 68412-69-1) Colorless Liquid.[13] (52299-25-9) Solid[14] "No specific physical or chemical property data were identified for the substances in this group. According to descriptive information in the patent literature (Heid, et al., 1975),[15] mixtures of PFPAs and PFPIAs are stable towards heat, acid and oxidation. The substances in this group are expected to be surface active.[16]
Melting point; Boiling point	(52299-25-9) MP: 47-53˚C ; BP: 216-243˚C[17]
Solubility	Water Soluble.[18]
Specific Gravity	No data available
SAFETY/PHYSICAL HAZARDS	
Vapor Pressure	5.21E-04 mm of Hg (Howard and Muir, 2010).[19]
Flammability	No data available
Flashpoint	No data available

Flammability Rating	No data available
Auto Ignition Point	No data available
Combustion products	Non-Combustible.[20]
Explosivity (UEL, LEL, shock sensitive)	No data available
Oxidizer	No data available
Corrosivity	The acid dissociation constants (pK_A) for PFPAs and PFPIAs with long perfluoroalkyl chain substituents were inferred by (Lee, et al., 2017)[21] from the measured pK_A of homologous phosphonic and phosphinic acids with short perfluoroalkyl chain substituents: PFPA (methyl and propyl homologues; pK_{A1} = 0.9–1.2; pK_{A2} = 3.9); PFPIA (dimethyl homologue; pK_A < 1). The low measured pK_A values for these analogues indicate that the constituent acids of the substances in this group are expected to be strong organic acids. Therefore, they are expected to readily dissociate in water to release organic mono- and di-anions from PFPA, and mono-anions from PFPIA."
pH	"According to application testing information in the patent literature, mixtures of PFPAs and PFPIAs with chains of six to 12 per fluorinated carbon atoms are useful for their intended purpose as foam-dampening agents over a wide pH range (1–12) at concentrations in the range 0.001 to 0.1 grams per liter (Heid, et al., 1975)."[22]
Reactivity	No data available
Viscosity	No data available
Odor Threshold	No data available
Particle size, shape, respirable fraction	No data available
Other physical hazards associated with process: Heat, gases under pressure, noise, vibration, ergonomic hazard	No data available
HEALTH HAZARDS	
Acute Toxicity	
Oral LD_{50}	>50 and <300 mg/kg bw through Rat test for acute oral toxicity (52299-25-9)[24] Acute Tox. 4-H302-Harmful if swallowed (68412-68-0)[25] Acute Tox. 3-Toxic if swallowed (52299-25-9)[26] LC_{50} = >10 and <100 mg/l for a mixture of PFPAs and PFPiAs through 96-h Zebrafish test (Wang, et al.,2016).[27]
Dermal LD_{50}	No data available
Inhalation LC_{50}	No data available
Intraperitoneal LD_{50}	No data available

Chronic or Sub-chronic Toxicity	
IARC rating	No data available
Carcinogenicity	No data available
Neurotoxicity	No data available
Developmental/Reproductive Toxicity	"Developmental toxicity for a mixture of PFPAs and PFPIAs was investigated in a preliminary study in which 5–40 milligrams per kilogram body-weight per day (mg/kg bw/day) Masurf-780 was fed to pregnant mice daily through the gestation period. Neonatal survival and growth were unaffected except in the highest dose group of 40 mg/kg bw/day. Increased maternal liver weight was observed at 30 and 40 mg/kg bw/day. These results thus suggest that PFPA exposure during pregnancy did not compromise neonatal survival and postnatal growth to the extent seen with PFOS and PFOA, but the hepatic effects appeared to be common to all classes of PFAAs. This abstract does not necessarily reflect U.S. EPA policy."[29]
Genotoxicity/Mutagenicity	A study on Chlamydomonas Reinharditii to evaluate toxicity of PFPAs revealed that C10 PFPA induces the oxidative stress on Chlamydomonas Reinharditii and impact the transcription of antioxidative related genes (Sanchez, et at., 2015).[30] *See aquatic toxicity too.*
Endocrine Disruption	No data available
Thyroid	Exposure to 8:8 PFPiA resulted in significantly enhanced levels of T4 and T3, reduced body length and heart rate, which may be a result of thyroid endocrine disturbance in zebrafish (Liu, et al., 2019).[31]
Immunotoxicity	No data available
Other organ toxicity	"In experiment one, adult male CD-1 mice received 0 (control), 10.4 or 41.6 mg/kg bw of Masurf-780 once daily for seven days by oral gavage. In a second experiment, SV129 wild-type (WT) and peroxisome proliferator-activated receptor alpha (PPARa)-null male mice (null) were similarly dosed with Masurf FS-780 at 0 (control), 3.1 or 20.8 mg/kg bw/day. All mice were sacrificed 24 h after the last treatment. No deaths were reported. Dose-dependent increases in liver weight were found in CD-1 and SV129 WT mice but not in null mice. Hence, like other PFAAs, PFPAs appear to function as an activator of PPARa. These results suggest that PFPA-induced liver enlargement occurs specifically through activation of PPARa (Das et al, 2011)."[32]
Skin, Eye and Respiratory Effects	
*Irritant – **S**kin, **E**ye, or **R**espiratory*	No data available
*Corrosive – **S**, **E**, or **R***	No data available
*Permanent Damage – **S**, **E**, or **R***	Eye Damage 1-H318: Causes serious eye damage (52299-25-9)[33]
*Sensitizer– **S** & **R***	No data available

Asthmagen – Initiator or Exacerbator	No data available
Skin Absorption, Kp	No data available
LOAEL	No data available
NOAEL	No data available
Benchmark Dose Response (BMD)	No data available
Toxicokinetics	No data available
Metabolites	No data available
Synergistic or Antagonistic Effects	No data available
Environmental and Human Health Exposure and Risk Values	
RfC/RfD	No data available
ATSDR-MRL	No data available
Adverse Effect Levels: DNEL, PNEC, PNEL	"Use of the substances in this group will result in the environmental release of PFPAs and PFPIAs, which are extremely persistent and may be bio-accumulative. These hazard characteristics combined have the potential to result in a range of long-term effects on organisms exposed to the chemicals which cannot be readily identified through standard ecotoxicity tests. For such chemicals, it is not currently possible to estimate a safe exposure concentration using standard extrapolation methods based on laboratory screening level tests. PNECs have therefore not been derived for the chemicals in this group."[34]
Health Based Exposure Limits	
NIOSH-REL/IDLH/Ceiling Limits	No data available
OSHA-PEL	No data available
ACGIH TLV-TWA	No data available
TLV-STEL	No data available
Biomonitoring Action Limits	No data available
Drinking Water Standards	No data available
Other	No data available
ENVIRONMENTAL & ECO-SYSTEM HAZARDS	
PBT	
Persistent	**PFPAs** are likely to be persistent and long-range transportable, whereas **PFPiAs** may transform to PFPAs and possibly PFCAs in the environment and biota. "A plausible pathway has been identified for the biotransformation of PFPIAs to PFCAs. This pathway involves cleavage of the C–P bond of PFPIAs to release 1*H*-perfluoroalkanes which are defluorinated and oxidised to give a PFCA with one less perfluorinated carbon atom than is present in the 1*H*-perfluoroalkane metabolite. According to this scheme, PFPIAs with a perfluorooctyl chain can be metabolised to perfluorooctanoic acid. Hence, PFPIAs with at least one perfluorooctyl substituent are indirect precursors to PFOA, which is of high concern to human health and the environment."[35]

Bioaccumulation	**PFPA:** Resistant to heat, oxidants, bases and aerobic biodegradation in surface water (Wang, et al., 2016). Does not breakdown readily from natural processes, accumulates in organisms concentrating as it moves up the food chain and is harmful in small quantities.[36] **PFPiA:** Hydrolyze to yield PFPA when heated or alkalized; bio transform to yield PFPA in rainbow trout and possibly rats (Wang, et al.,2016).[37] **PFPA:** Substances bind to proteins (proteinophilic) and accumulate in blood, kidney and liver: elimination half-lives increase with increasing perfluoroalkyl chain length; PFPA with $\geq C_8$ have long elimination half-life fin rainbow trout and rats (Lee et al., 2012)[38], (D'Eon, et al.,2009). **PFPiA:** Same as PFPA except they just bind to proteins or plasma components but not blood cells (D'Eon, et al., 2009).[39] The bioaccumulation potential is influenced by both the perfluoroalkyl chain length and the head group and varies between sexes and species (Wang, et al., 2016).[40] PFPAs are eliminated rapidly from rats. After dosing by oral gavage, the elimination half-life of C8 PFPA was calculated to be 0.95 days, with no C8 PFPA able to be detected in blood samples after 4 days. The elimination half-life for C8/C8 PFPIA administered to rats by oral gavage is 2.8 days. These elimination half-lives are shorter than those observed for PFOA (< 6 days) and PFOS (43 days). Metabolism of PFPIAs to PFPAs and excretion of this di-anionic PFAA may be responsible for the faster elimination of PFPIAs from rats than other mono-anionic PFAAs (Joudan, et al., 2017).[41] A study measured PFPAs and PFPiAs in fish, birds, and marine mammals and every animal analyzed contained both contaminants. Younger and smaller dolphins tended to have higher PFPiA concentrations. This was the first study to report of PFPiA relating to size and age in any species (De Silva et al., 2016).[42] One study showed the level of detection of PFPA for C8 in drinking water (<0.32 ng/L) in the Netherlands (Ullah, et al., 2011).[43] "Further, PFPiAs were recently detected in tissues of lake trout (Salvelinus namaycush) from the Great Lakes, ranging between 0.001

	and 0.032 ng/g wet weight, indicating PFPiAs can accumulate in wild fish (Guo et al., 2012)."[44] "More recently, dietary bioaccumulation of three PFPiAs and three PFPAs were investigated using juvenile rainbow trout (Lee et al., 2012).[45] The authors found that PFPiAs were metabolized to PFPAs and did not bio magnify in these fish, as demonstrated by biomagnification factors (BMFs, C_{fish}/C_{food}) < 1."
BAF	6:6 PFPiA have higher log K_{OW} but displayed lower log BAFs. It may be because of experiencing enzyme-catalyzed transformation or the large molecular size of PFPIAs that make them difficult to penetrate cell membranes and limit their bioaccumulation potential (Chen, et al., 2018). [46] Similar to other perfluorinated chemicals, PFPAs and PFPIAs have high affinities for proteins (i.e., they are proteophilic) and they tend to partition to protein-rich tissues (D'Eon, et al., 2010)[47], (Hungerbühler, et al., 2014).[48] This behavior is distinct from lipophilic bio-accumulative substances, which typically partition to fatty tissues.
BCF	**"**C6–C12/C6–C12 PFPIA has high bioconcentration potential in fish and uncertain biomagnification potential in air-breathing animals. C6–12 PFPA has low bioconcentration potential in fish and uncertain biomagnification potential in air-breathing animals."[49] In a bioconcentration study conducted according to OECD TG 305, zebrafish were exposed to a technical mixture of PFPAs and PFPIAs. Measured bioconcentration factor (BCF) values indicated that PFPIAs had very high bioconcentration potential, with a lowest measured whole-body BCF for C6/C6 PFPIA of 41 700 L/kg, significantly exceeding the domestic categorization threshold of 2000 L/kg (Chen, et al., 2016).[50] BCF (52299-25-9): 799[51]
BMF	In a biomagnification study, dietary exposure of a mixture of C6/C6, C6/C8 and C8/C8 PFPIAs in juvenile rainbow trout gave biomagnification factors (BMF) of less than one for each congener (Lee, et al., 2012).[52] The biotransformation of PFPIAs in fish as an additional depuration pathway contributed to these low BMF values. BMFs of less than one indicates that these chemicals have low potential to accumulate through aquatic food webs. However, the biomagnification potential of

<table>
<tr><td></td><td>PFASs are known to differ between piscivorous and marine mammalian food webs (Kelly, et al., 2009)[53], indicating that these measured BMF values cannot be used to infer the biomagnification potential of PFPIAs in air-breathing animals.

Dietary exposure gave BMFs significantly less than one for the C6, C8 and C10 homologues in juvenile rainbow trout, indicating low biomagnification potential in fish (Lee, et al., 2012).[54]</td></tr>
<tr><td>Ecological Toxicity</td><td>Concentrations of PFPA and PFPIAs in water (ng/L) and sediment (ng/g dw) samples from Taihu Lake are (Chen. M., et al., 2018):[55]
Water: 6:6 PFPIAs <0.002–0.020 ng/L
Sediment: 6:6 PFPIAs <0.0004–0.010 ng/L</td></tr>
<tr><td>Aquatic Toxicity: LC_{50}, EC_{50}, ErC_{50}, NOAEC/NOEC</td><td>Aquatic Chronic 3-(H412)-Harmful to aquatic life with long lasting effects.[56]

Inherent Toxicity to Aquatic Organisms: (eChem portal)[57]
<table>
<tr><td>Pivotal value for iT (mg/l)</td><td>0.084</td></tr>
<tr><td>Toxicity to fish (LC50 in mg/l) as predicted by Oasis Forecast M v1.10</td><td>0.1111</td></tr>
<tr><td>Toxicity to fish, daphnia, algae or mysid shrimp (EC50 or LC50 in mg/l) as predicted by Ecosar v0.99g</td><td>0.084</td></tr>
<tr><td>Chronic toxicity to daphnia or algae (EC50 in mg/l) as predicted by Ecosar v0.99g</td><td>0.121</td></tr>
<tr><td>Toxicity to fish (LC50 in mg/l) as predicted by Neutral Organics QSAR in Ecosar v0.99g</td><td>8.41E-004</td></tr>
</table>

A study on the green algae Chlamydomonas Reinharditii revealed that C10 PFPA induces the oxidative stress on the green algae and impacts the transcription of genes related to the cell antioxidant defense system (Sanchez, et at., 2015).[58] See Genotoxicity too.</td></tr>
<tr><td>Mammalian Toxicity: LC_{50}, EC_{50}, ErC_{50}, NOAEC/NOEC</td><td>“PFPIAs are metabolized to PFPAs and 1H-perfluoroalkanes in fish and mammals. Biotransformation of PFPAs has not been observed.”[59]</td></tr>
<tr><td>Wildlife Toxicity: LC_{50}, EC_{50}, ErC_{50}, NOAEC/NOEC</td><td>No Data Available</td></tr>
<tr><td>Breakdown/degradation /combustion products</td><td>PFPA: 0% degradation of C6, C8 and C10 in OECD 309 tests
PFPiA: Degrade to PFPA in rainbow trout and possibly in rats (Lee et al., 2012). 0% degradation of C4/C4 PFPiA in OECD 301 tests (Wang, et al., 2016).

“PFPAs and PFPIAs are resistant to abiotic degradation. The PFPA degradation products in fish were observed at the highest concentrations</td></tr>
</table>

	in the liver, blood and kidneys, suggesting that the liver and kidneys may be the sites of biotransformation."[60]
Anaerobic degradation	No Data Available
Aerobic degradation	No Data Available
Other observable ecological effects (e.g. BOD)	No Data Available
Fate and Transport: Aquatic	"The long-range transport potential of PFPAs and PFPIAs is uncertain. PFPAs and PFPIAs have been identified in multiple locations worldwide (Chen, et al., 2018, D'Eon, et al., 2009, De Silva, et al., 2016, Esparza, et al., 2011, Hlouskova, et al., 2013, Loi, et al., 2013). These PFAAs have also been measured in biological samples on three continents (Wang, et al., 2016). The high persistence and water solubility of PFPAs may lead to these chemicals being transported in water to remote regions."[61]
Fate and Transport: Terrestrial	No Data Available
Fate and Transport: Atmospheric	No Data Available
Transport Issues	No Data Available
Factors affecting bioavailability	No Data Available
Global Environmental Impacts	
Ozone Depletion Potential (ODP)	No data available
Global Climate Change	No data available
Greenhouse Gas Production	No data available
Acid Rain Formation	No data available
Special Reports	
EU/Other Countries	Domestic Substances List (DSL) and being managed following assessment under Canada's Action Plan for Long-Chain Perfluorocarboxylic Acids.

[1] www.toxplanet.com; Chemical Identity Page for Phosphonic acid.
[2] www.toxplanet.com; No data available.
[3] ChemID Database, Accessed online: https://chem.nlm.nih.gov/chemidplus/: EINECS for Phosphonic acid CAS#: 68412-68-0 and 68412-69-1
[4] U.S. National Library of Medicine, ChemIDplus, a Toxnet Database, entry for "CAS#68412-68-0 and 68412-69-1", Accessed online at: https://chem.nlm.nih.gov/chemidplus/rn/68412-68-0 and https://chem.nlm.nih.gov/chemidplus/rn/68412-69-1
[5] National Industrial of Chemical Notification and Assessment Scheme, Accessed at: https://www.nicnas.gov.au/chemical-information/imap-assessments/imap-assessments/tier-ii-environment-assessments/pfpas_pfpias#Physical
[6] EPA Database entry for "CAS#68412-68-0 and select all for Manufacturing, Processing, Use, and Release Data Maintained by EPA" Accessed online at: https://chemview.epa.gov/chemview
[7] EPA Database entry for "CAS#68412-68-0 and select all for Manufacturing, Processing, Use, and Release Data Maintained by EPA" Accessed online at: https://chemview.epa.gov/chemview
[8] EPA Database entry for "CAS#68412-68-0 and select all for Manufacturing, Processing, Use, and Release Data Maintained by EPA" Accessed online at: https://chemview.epa.gov/chemview

[9](**Heid, et al, 1975):** Heid C, Hoffmann D and Polster J (1975), Use of perfluoralkylphosphorus compounds as foam dampening agents. Cassella Farmworker Mainkur AG, Frankfurt, Germany, USA. Accessed at https://patents.google.com/patent/US3912654A/en?q=B01D19%2f0418

[10]**(Howard and Muir, 2010):** Howard PH and Muir DCG (2010). Identifying New Persistent and Bioaccumulative Organics Among Chemicals in Commerce. Environmental Science & Technology, **44**(7), pp 2277-2285. Accessed at: https://pubs.acs.org/doi/10.1021/es903383a

[11]**(Wang, et al.,2016):** Comparative assessment of the environmental hazards of and exposure to perfluoroalkyl phosphonic and phosphinic acids (PFPAs and PFPiAs): Current knowledge, gaps, challenges and research needs. Journal of Environment International, 89–90 (2016) 235–247 Accessed at: https://www.sciencedirect.com/science/article/pii/S0160412016300241?via%3Dihub

[12]**(OECD, 2007):** OECD (2017). Lists of PFOS, PFAS, PFOA, PFCA, Related Compounds and Chemicals That May Degrade to PFCA. Organization for Economic Cooperation and Development, Paris, France. Accessed at: http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?doclanguage=en&cote=env/jm/mono(2006)15

[13]Material Safety Data Sheet. Accessed online at: https://www.guidechem.com/reference/dic-837340.html#Properties

[14] European Chemical Agency (ECHA) Information on registered substances: Brief Profile for bis(nonafluorobutyl)phosphinic acid, accessed 8AUG2019 at:https://echa.europa.eu/brief-profile/-/briefprofile/100.148.926

[15](**Heid, et al, 1975):** Heid C, Hoffmann D and Polster J (1975), Use of perfluoralkylphosphorus compounds as foam dampening agents. Cassella Farmworker Mainkur AG, Frankfurt, Germany, USA. Accessed at https://patents.google.com/patent/US3912654A/en?q=B01D19%2f0418

[16] National Industrial of Chemical Notification and Assessment Scheme, Accessed at: https://www.nicnas.gov.au/chemical-information/imap-assessments/imap-assessments/tier-ii-environment-assessments/pfpas_pfpias#Physical

[17] European Chemical Agency (ECHA) Information on registered substances: Brief Profile for bis(nonafluorobutyl)phosphinic acid, accessed 8AUG2019 at:https://echa.europa.eu/brief-profile/-/briefprofile/100.148.926

[18] Material Safety Data Sheet. Accessed online at: https://www.guidechem.com/reference/dic-837340.html#Properties

[19]**(Howard and Muir, 2010):** Howard PH and Muir DCG (2010). Identifying New Persistent and Bioaccumulative Organics Among Chemicals in Commerce. Environmental Science & Technology, **44**(7), pp 2277-2285. Accessed at: https://pubs.acs.org/doi/10.1021/es903383a

[20]Material Safety Data Sheet. Accessed online at: https://www.guidechem.com/reference/dic-837340.html#Properties

[21]**(Lee, et al., 2017):** Lee H and Mabury SA (2017). Sorption of Perfluoroalkyl Phosphonates and Perfluoroalkyl Phosphinates in Soils. Environmental Science & Technology, **51**(6), pp 3197-3205. Accessed at: https://www.ncbi.nlm.nih.gov/pubmed/28222593

[22](**Heid, et al, 1975):** Heid C, Hoffmann D and Polster J (1975), Use of perfluoralkylphosphorus compounds as foam dampening agents. Cassella Farmworker Mainkur AG, Frankfurt, Germany, USA. Accessed at https://patents.google.com/patent/US3912654A/en?q=B01D19%2f0418

[24] European Chemical Agency (ECHA) Information on registered substances for bis(nonafluorobutyl)phosphinic acid CAS # 52299-25-9, accessed 14AUG2019 at: https://echa.europa.eu/registration-dossier/-/registered-dossier/8036/2/1

[25] European Chemical Agency (ECHA) Information on registered substances: Classification and Labeling Inventory Database, accessed 8AUG2019 at: https://echa.europa.eu/information-on-chemicals/cl-inventory-database/-/discli/details/114467

[26] European Chemical Agency (ECHA) Information on registered substances for bis(nonafluorobutyl)phosphinic acid CAS # 52299-25-9, accessed 14AUG2019 at: https://echa.europa.eu/registration-dossier/-/registered-dossier/8036/2/1

[27] **(Wang, et al.,2016):** Comparative assessment of the environmental hazards of and exposure to perfluoroalkyl phosphonic and phosphinic acids (PFPAs and PFPiAs): Current knowledge, gaps, challenges and research needs. Journal of Environment International, 89–90 (2016) 235–247 Accessed at: https://www.sciencedirect.com/science/article/pii/S0160412016300241?via%3Dihub

[29] United States Environmental Protection Agency (EPA). Select Environmental topics then Science Inventory and search for Developmental Toxicity of Perfluoro Alkyl Phosphonic Acid. Accessed at: https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=235687&Lab=NHEERL&keyword=treatment+AND+water+AND+grey&actType=&TIMSType=+&TIMSSubTypeID=&DEID=&epaNumber=&ntisID=&archiveStatus=Both&ombCat=Any&dateBeginCreated=&dateEndCreated=&dateBeginPublishedPresented=&dateEndPublishedPresented=&dateBeginUpdated=&dateEndUpdated=&dateBeginCompleted=&dateEndCompleted=&personID=&role=Any&journalID=&publisherID=&sortBy=revisionDate&count=50

[30] **(Sanchez, et al., 2015):** Sanchez D, Houde M, Douville M, De Silva AO, Spencer C, Verreault J (2015) Transcriptional and cellular responses of the green alga Chlamydomonas reinhardtii to perfluoroalkyl phosphonic acids. Aquatic Toxicology, **160**, pp 31-38. Accessed at: https://www.ncbi.nlm.nih.gov/pubmed/25621396

[31] **(Liu, Menglin, et al, 2019):** Thyroid endocrine disruption effects of perfluoroalkyl phosphinic acids on zebrafish at early development. Science of The Total Environment, Volume 676, Pages 290-297accessed at: https://doi.org/10.1016/j.scitotenv.2019.04.177

[32] DAS, K., P. Rosen, B. Mitchell, C. R. WOOD, B. D. ABBOTT, AND C. LAU. PERFLUOROPHOSPHONIC ACID ACTIVATES PEROXISOME PROUFERATOR-ACTIVATED RECEPTOR-ALPHA BUT NOT CONSTITUTIVE ANDROSTANE RECEPTOR IN THE MURINE LIVER. Presented at Society of Toxicology (SOT) Annual Meeting, Washington, DC, March 06 - 10, 2011.

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