Ethane, pentafluoro-: Environment tier II assessment

07 February 2014

CAS Registry Number: 354-33-6.

Preface

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

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

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

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

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

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

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

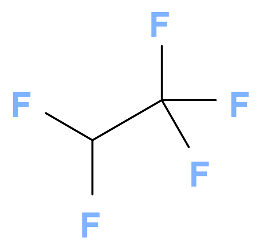
This chemical or group of chemicals are being assessed at Tier II because the Tier I assessment indicated that it needed further investigation.

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

Disclaimer

Acronyms & Abbreviations

Chemical Identity

Synonyms	HFC 125 1,1,1,2,2-Pentafluoroethane Pentafluoroethane Freon 125 R 125
Structural Formula	

Molecular Formula	C_2HF_5
Molecular Weight (g/mol)	120.02
SMILES	C(F)(F)(F)C(F)F

Physical and Chemical Properties

The physical and chemical property data for the chemical were retrieved from the databases included in the OECD QSAR Toolbox (LMC, 2013).

Physical Form	Gas
Melting Point	-103°C (exp.)
Boiling Point	-48.5°C (exp.)
Vapour Pressure	1 400 000 Pa (exp.)
Water Solubility	3890 mg/L (exp.)
Ionisable in the Environment?	No
log K_{ow}	1.48 (exp.)

Import, Manufacture and Use

Australia

Ethane, pentafluoro- (HFC 125) is a hydrofluorocarbon (HFC) gas imported into Australia for use in commercial and domestic refrigeration and air conditioning applications. Hydrofluorocarbons are further used in foam blowing, in fire suppression applications and aerosols (Australian Government Department of Climate Change, 2013; DSEWPaC, 2013).

The chemical is commonly used to replace ozone depleting chemicals, such as chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), that are being phased out under the *Montreal Protocol on Substances that Deplete the Ozone Layer* (the Montreal Protocol). Import, export and manufacture of the chemical requires a licence under the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* (Cwlth) (the Ozone Act) (Australian Government Department of Climate Change, 2013; Commonwealth of Australia, 1989).

The chemical is primarily imported in mixtures with other HFCs. HFC 125 is contained in the refrigerant gas mixtures HFC 404a, HFC 407a, HFC 407b, HFC 407c, HFC 410a and HFC 507a at concentrations of 44%, 40%, 70%, 25%, 50% and 50%, respectively. Almost 3000 tonnes of HFC 125 was imported into Australia in HFC mixtures in 2012, primarily in HFC 404a and HFC 410a. HFC 404a is predominantly used in refrigeration, with almost 950 tonnes of HFC 125 imported in bulk HFC 404a in 2012. Use of HFC 404a is decreasing in favour of HFC 134a. Conversely, import of HFC 410a is increasing due to higher demand for the air conditioning systems the chemical is used in. Over 750 tonnes of HFC 125 was imported into Australia in 2012 contained in equipment pre-charged with HFC 410a, while approximately an additional 1000 tonnes of HFC 125 was imported in bulk HFC 410a (AIRAH and IRHACE, 2007; DSEWPaC, 2013).

It was estimated that almost 9000 tonnes of HFC 125 was contained in equipment in Australia in 2012. A small proportion of HFC 125 in Australia may be re-exported, with an additional proportion reclaimed and destroyed (DSEWPaC, 2013).

Use of the chemical has increased significantly since the commencement of the Montreal Protocol. Between 1990 and 2011, use of HFCs rose by 578% in Australia. In 2011, HFCs comprised 1.5% of Australia's greenhouse gas emissions (measured in carbon dioxide equivalents). Approximately one fifth of this value is attributable solely to HFC 125 emissions (Australian Government Department of Climate Change, 2013).

International

The majority of HFC 125 is used in commercial refrigeration and air conditioning systems. Minor applications include use as a fire extinguisher, in foam blowing, and as a solvent (OECD, 2005). Global emissions of the chemical were estimated to be between 9000 and 10 000 tonnes in 2002 (IPCC, 2005). However, use of the chemical internationally is rising due to the use of HFCs to replace chemicals being phased out under the Montreal Protocol. Almost 38 000 tonnes of the chemical was manufactured in the United States of America (USA) in 2012 (US EPA, 2013a).

The chemical is registered for various uses under the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) legislation at 10 000 to 100 000 tonnes per annum in the European Union (ECHA, 2013a). Use in the European Union is nevertheless controlled, with various emissive uses of the chemical prohibited (European Commission, 2006).

Recent developments have highlighted the potential for an international agreement to phase down the use of HFCs. At the Group of Twenty (G20) meeting in September 2013, 26 countries (including Australia, the USA and the European Union) agreed to support initiatives to phase down the production and consumption of HFCs. This followed proposals by the USA, Canada, Mexico, and the Federated States of Micronesia in April 2013 to amend the Montreal Protocol to address HFCs (UNEP, 2013a; 2013b).

Environmental Regulatory Status

Australia

HFC 125 is a scheduled substance under the Ozone Act. A licence is required to import, export or manufacture the chemical, unless the chemical is used on board ships or aircraft which are transiting between Australia and a place outside Australia. Import and manufacture of the chemical incurs a levy under the *Ozone Protection and Synthetic Greenhouse Gas (Import Levy) Act 1995* (Cwlth) and the *Ozone Protection and Synthetic Greenhouse Gas (Manufacture Levy) Act 1995* (Cwlth), respectively. Additionally, the quantity of the chemical that is imported or manufactured must be reported on a quarterly basis to the Australian Government Department of the Environment which administers the Ozone Act (Commonwealth of Australia, 1989).

Under the *Ozone Protection and Synthetic Greenhouse Gas Management Regulation 1995* (Cwlth), only certified personnel may carry out work on refrigeration and air conditioning equipment containing the chemical, or possess bulk volumes of the chemical. Certified personnel must operate in accordance with relevant Australian Standards and codes of practice which set out requirements for minimising leakages and gas emissions (Commonwealth of Australia, 1995).

United Nations

HFCs are listed as greenhouse gases on Annex A of the *Kyoto Protocol to the United Nations Framework Convention on Climate Change* (UNFCCC, 1998). The Kyoto Protocol calls for a reduction in emission of greenhouse gases to the environment. Of the 197 countries of the United Nations, 192 have ratified the Kyoto Protocol, including Australia (UNFCCC, 2013).

Since 2009, numerous proposals to phase-down the production and consumption of HFCs have been made under the Montreal Protocol. To date, there has not been consensus to negotiate any such phase-down (UNEP, 2012).

OECD

The chemical was sponsored by the United States of America (USA) under the Cooperative Chemicals Assessment Programme (CoCAP). The 20thScreening Information Data Set (SIDS) Initial Meeting Assessment (SIAM 20) in 2005 agreed that the chemical was a low priority for further work due to the low hazard profile to human health and the environment, and the management of the global warming potential of the chemical through other programmes (OECD, 2005).

Canada

The chemical is listed on Schedule 1 of the *Federal Halocarbon Regulations, 2003*. Systems intended to operate with the chemical cannot be installed without a permit. Additionally, a permit is required to use the chemical as a solvent in solvent systems. Only certified personnel may install, service, leak test or charge a refrigeration or air conditioning system, and use of the chemical is subject to exposure restrictions and reporting requirements.

The chemical is also listed on Schedule 1 of the *Canadian Environmental Protection Act 1999* (the Toxic Substances List). Emissions of the chemical must be reported under the National Pollutant Release Inventory. The chemical is further subject to a Significant New Activity rule, whereby any new uses of the chemical constituting more than 1 tonne in volume (excluding use in closed loop cooling systems) must be assessed and approved before use can commence (Environment Canada, 2013a; Government of Canada, 2006).

The chemical was not categorised during the Categorization of the Domestic Substances List (DSL) (Environment Canada, 2013b).

European Union

Use of the chemical for most applications in the European Union is controlled under *Regulation No 842/2006 of the European Parliament and of the Council of 17 May 2006 on Certain Fluorinated Greenhouse Gases*. Use of the chemical for non-confined refrigeration systems, windows, footwear, tyres, novelty aerosols and one component foams (except when required to meet national safety standards) is prohibited. Additionally, use is subject to emission restrictions (leakage prevention), training of personnel, labelling and reporting requirements (European Commission, 2006).

The European Union is expected to adopt regulations in the foreseeable future to begin phase-down use of HFCs and ban the use of select HFCs in some equipment, including domestic and commercial refrigerators and air conditioning systems (European Commission, 2014).

United States of America

Servicing of refrigeration and air conditioning systems, including those in refrigerated transport vehicles, containing the chemical is regulated under the *Clean Air Act 1970*. Intentional release of the chemical from an air conditioner, refrigerator, chiller or freezer is prohibited (US EPA, 2013b).

Environmental Exposure

HFC 125 is primarily used as a refrigerant in Australia. Although refrigerants generally operate in closed systems, the chemical may be lost through leakages. Leakage rates for HFCs used in refrigerant applications range from approximately 1% of the total volume per annum in modern domestic refrigerators to as high as 25% of the total volume per annum in refrigeration transport vehicles (DSEWPaC, 2013).

In 2011, more than 550 tonnes of HFC 125 is estimated to have been released to the environment in Australia. The majority of this release is expected to have occurred due to leakages and losses from refrigeration and air conditioning systems (Australian Government Department of Climate Change, 2013; DSEWPaC, 2013).

Environmental Fate

Partitioning

The chemical is expected to partition to the atmosphere when released from typical industrial uses.

The calculated Henry's Law constant for partitioning of HFC 125 from water to air is 309 000 Pa-m^3/mol (US EPA, 2008), indicating that the chemical is highly volatile from water and moist soil. Calculated organic carbon normalised adsorption coefficients (log K_{OC}s) for the chemical range from 1.3 to 2.1 (US EPA, 2008), suggesting that the chemical is highly mobile in soil. However, evaporative losses are expected to dominate the partitioning and transport of the chemical in soil.

Calculations with a standard multimedia partitioning (fugacity) model assuming equal and continuous distributions to air, water and soil compartments (Level III approach) predict that the chemical will mainly partition to air (52%) and water (47%) compartments, with minor partitioning to soil (< 1%). However, with sole release to the atmosphere, the model predicts that 100% of the chemical will remain in the air compartment (US EPA, 2008). The latter scenario is expected to be the more likely route for release of this chemical to the environment.

Degradation

Degradation of the chemical in the atmosphere is slow.

The chemical has a predicted overall atmospheric lifetime of 28.2 years, based on reactions with hydroxyl radicals in the troposphere and destruction in the stratosphere (WMO, 2011). As HFC 125 is expected to partition to the atmosphere, these are expected to be the predominant degradation processes for the chemical in the environment.

The major degradation process for HFC 125 in the atmosphere is oxidation. The chemical has low reactivity towards indirect photo-oxidation by hydroxyl radicals in the troposphere with an estimated lifetime of 32 years for degradation by these reactions (WMO, 2011). Due to its low reactivity, a proportion of the chemical will be transported through the troposphere to the stratosphere, where it may undergo degradation by means of photo-oxidation or ultraviolet (UV) photolysis. The fluorinated organic compounds, carbonyl fluoride (COF_2) and trifluoromethanol (CF_3OH), are produced as degradation products (IPCC, 2005).

In water and soil, HFC 125 is not expected to be rapidly degraded under aerobic conditions. The aerobic biodegradation of the chemical was determined to be 5% in 28 days in a study conducted in accordance with OECD Test Guideline (TG) 301 D (OECD, 2005).

Bioaccumulation

The chemical is not expected to bioaccumulate in aquatic or terrestrial organisms.

No specific measured bioconcentration or bioaccumulation data are available for the chemical. However, based on the measured octanol water partition coefficient (log K_{OW} = 1.48), the chemical is expected to have low potential for bioaccumulation in the environment.

Transport

The chemical will undergo atmospheric transport, and long range transport is highly likely.

Due to the long atmospheric lifetime of the chemical, HFC 125 will become mixed throughout the atmosphere through atmospheric transport (IPCC, 2005). Further, the long life time and volatility of the chemical is also expected to result in the chemical undergoing long range transport in the environment.

Predicted Environmental Concentration (PEC)

A PEC was not calculated for HFC 125 as there is a large body of high quality environmental monitoring data available from multiple sites around the world. As the chemical has no natural sources or significant non-industrial uses, measured environmental concentrations are expected to have resulted solely from industrial manufacture and use of the chemical. The abundance of the chemical in the air compartment in 2011 was found to be approximately 9.6 parts per trillion (ppt), up from 3.7 ppt in 2005, and continuing to increase (IPCC, 2013; WMO, 2011). Emissions of HFC 125 in Australia are currently increasing at a rate of approximately 50 tonnes per annum (Australian Government Department of Climate Change, 2013).

HFC 125 is not expected to have any significant presence in the water, soil or sediment compartments due to the partitioning behaviour of the chemical, and therefore PECs have not been calculated for these compartments.

Environmental Effects

Effects on the Atmosphere

HFC 125 does not deplete the ozone layer, but it does have a high global warming potential.

Photolysis of halocarbons containing chlorine and bromine can cause depletion of the ozone layer (WMO, 2011). As HFC 125 does not contain chlorine or bromine atoms, it does not contribute to ozone depletion. However, halocarbons with long atmospheric lifetimes such as HFC 125 contribute to global warming by absorbing radiation emitted from Earth and thus trapping the energy in the atmosphere (radiative forcing) (WMO, 2011). The amount of global warming that can be caused by a substance is typically reported in terms of the global warming potential (GWP) metric. The GWP is the ratio of the warming caused by the substance to the warming caused by the same mass of carbon dioxide, and is calculated for various time horizons (US EPA, 2010; WMO, 2011). HFC 125 has a one hundred year GWP of 2800 (IPCC, 2013).

Effects on Aquatic Life

HFC 125 is not expected to cause toxic effects in aquatic organisms at low concentrations.

Acute toxicity

The following median lethal concentrations (LC50s) and median effective concentration (EC50) for model organisms across three trophic levels were reported in the Registration Dossier for the analogue chemical ethane, 1,1,1,2-tetrafluoro- (HFC 134a) under the European Union REACH legislation, or calculated using the Neutral Organics QSAR models available in ECOSAR v1.11 (ECHA, 2013b; US EPA, 2012):

Taxon	Endpoint	Method
Fish	96 h LC50 = 450 mg/L	Analogue *Oncorhynchus mykiss* (Rainbow trout) EU Method C.1; semi-static
	96 h LC50 = 289 mg/L	Calculated Neutral Organics; ECOSAR v1.11
Invertebrates	48 h EC50 = 980 mg/L	Analogue *Daphnia magna* (Water flea) EU Method C.2; static Decreased mobility observed
	48 h LC50 = 156 mg/L	Calculated Neutral Organics; ECOSAR v1.11
Algae	96 h EC50 = 95.5 mg/L	Calculated Neutral Organics; ECOSAR v1.11

HFC 134a is considered an appropriate analogue for the acute aquatic ecotoxicological effects of HFC 125 due to the close similarity in the structure and physico-chemical properties of the two chemicals. HFC 134a is a highly volatile, inert chemical, which has a low octanol-water partition coefficient similar to that of HFC 125. Further, both HFC 125 and HFC 134a are categorised as having a non-polar narcotic mode of action for effects in aquatic organisms (LMC, 2013). The measured acute toxicity values for HFC 134a are therefore considered suitable to fill gaps in the acute aquatic ecotoxicity data for HFC 125.

Chronic toxicity

There are no suitable data available to evaluate the chronic effects of the chemical on aquatic organisms.

Predicted No-Effect Concentration (PNEC)

The PNEC for the chemical in the air compartment was not calculated as there are currently no suitable data available to evaluate the effects of this chemical on terrestrial organisms.

The PNECs for HFC 125 in the water, soil and sediment compartments were not calculated as the chemical is not expected to be released to, or significantly partition to, these compartments as a result of industrial use.

Categorisation of Environmental Hazard

The categorisation of the environmental hazards of HFC 125 according to domestic environmental hazard thresholds is presented below (EPHC, 2009; NICNAS, 2013):

Persistence

Persistent (P). Based on an overall atmospheric lifetime of 28.2 years, the chemical is categorised as Persistent.

Bioaccumulation

Not Bioaccumulative (Not B). Based on a measured log K_{OW} of 1.48, the chemical is categorised as Not Bioaccumulative.

Toxicity

Not Toxic (Not T). Based on the above presented calculated and analogue acute ecotoxicity data, the chemical is categorised as Not Toxic.

Summary

Ethane, pentafluoro- is categorised as:

- P
- Not B
- Not T

Risk Characterisation

Risk quotients (RQs) have not been calculated for this chemical.

HFC 125 is not an ozone depleting substance and industrial use of this chemical does not pose a risk to the ozone layer.

HFC 125 is a potent greenhouse gas and emissions of this chemical contribute to the total amount of atmospheric warming caused by the release of hydrofluorocarbon gases into the atmosphere. Analysis of use and emission estimation information for Australia indicates that significant emissions of this chemical to the atmosphere do occur. Based on domestic and international trend information, emissions of this chemical are increasing. Current industrial uses of HFC 125 are therefore increasing the risks associated with warming of the atmosphere.

The risks of ecotoxicological effects of the chemical to organisms in the water, soil and sediment compartments are expected to be low as HFC 125 is not expected to be released to, or significantly partition to, these compartments as a result of industrial use.

Key Findings

HFC 125 is used in Australia to replace chlorofluorocarbons and hydrochlorofluorocarbons phased out of use under the Montreal Protocol. Although the chemical does not contribute to ozone depletion, it has a high global warming potential and contributes to the radiative forcing caused by hydrofluorocarbon gases in the atmosphere.

The Ozone Act regulates the use of the chemical in Australia to reduce emissions during technical work. However, significant emissions to the atmosphere do occur during use. Due to the release of the chemical to the atmosphere during use, current industrial use of HFC 125 in Australia is increasing the risks of atmospheric warming. Based on this analysis, current and projected future uses of HFC 125 are of potential concern to the environment.

In light of the environmental risks associated with cumulative emissions of hydrofluorocarbon gases from industrial uses in Australia that have been identified in this assessment, and subject to any future Australian or international regulatory action regarding these chemicals, a Tier III assessment under the IMAP framework may be warranted.

The chemical is not a PBT substance according to domestic environmental hazard criteria.

Recommendations

It is recommended that the Australian Government Department of the Environment review existing emission controls under the Ozone Act with a view to considering any improvements or additional actions that could be undertaken to minimise emissions of HFC 125 to the environment.

Environmental Hazard Classification

In addition to the categorisation of environmental hazards according to domestic environmental thresholds presented above, the classification of the environmental hazards of ethane, pentafluoro- according to the third edition of the United Nations' Globally Harmonised System of Classification and Labelling of Chemicals (GHS) is presented below (UNECE, 2009):

Hazard	GHS Classification (Code)	Hazard Statement
Acute Aquatic	-	Not classified

There are insufficient reliable data to classify the long-term aquatic hazards of the chemical.

References

AIRAH and IRHACE (2007). *Australia and New Zealand Refrigerant Handling Code of Practice 2007*. Australian Institute for Refrigeration, Air Conditioning and Heating and Institute of Refrigeration, Heating and Air Conditioning Engineers New Zealand, Australia. http://www.arctick.org.

Australian Government Department of Climate Change (2013). *Australia's Sixth National Communication on Climate Change*. Australian Government Department of Climate Change, Canberra, Australia. http://unfccc.int.

Commonwealth of Australia (1989). *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989*. The Ozone Act.

Commonwealth of Australia (1995). *Ozone Protection and Synthetic Greenhouse Gas Management Regulations 1995*.

DSEWPaC (2013). *Cold Hard Facts 2*. Department of Sustainability, Environment, Water, Population and Communities, Canberra, Australia. http://www.environment.gov.au.

ECHA (2013a). *Pentafluoroethane*. European Chemicals Agency, Helsinki, Finland. Accessed 17 December 2013 at http://apps.echa.europa.eu.

ECHA (2013b). *Norflurane*. European Chemicals Agency, Helsinki, Finland. Accessed 19 December 2013 at http://apps.echa.europa.eu.

Environment Canada (2013a). *Hydrofluorocarbons that have the molecular formula CnHxF(2n+2-x) in which 0<n<6*. Environment Canada, Gatineau, Quebec. Accessed 17 December 2013 at http://www.ec.gc.ca.

Environment Canada (2013b). *Search Engine for the Results of DSL Categorisation*. Environment Canada, Gatineau, Quebec, Canada. Accessed 21 November 2013 at http://www.ec.gc.ca.

EPHC (2009). *Environmental Risk Assessment Guidance Manual for Industrial Chemicals*. Environment Protection and Heritage Council, Canberra, Australia. Accessed 9 December 2013 at http://www.scew.gov.au.

European Commission (2006). Regulation (EC) No 842/2006 of the European Parliament and of the Council of 17 May 2006 on Certain Fluorinated Greenhouse Gases. *Official Journal of the European Union,*(L 161),pp 1.

European Commission (2014). *Council endorses agreement on Commission's proposal to limit F-gases*. European Commission. Accessed 4 February, 2014 at http://ec.europa.eu.

Government of Canada (2006). Order 2006-87-07-01 Amending the Domestic Substances List. *Canada Gazette Part II,* **140**(24), pp 76.

IPCC (2005). *Safeguarding the Ozone Layer and the Global Climate System: Issues Relating to Hydrofluorocarbons and Perfluorocarbons*. Intergovernmental Panel on Climate Change, Geneva, Switzerland. http://www.ipcc.ch.

IPCC (2013). *Climate Change 2013: The Physical Science Basis*. Intergovernmental Panel on Climate Change, Geneva, Switzerland. http://www.ipcc.ch.

LMC (2013). *The OECD QSAR Toolbox for Grouping Chemicals into Categories*, v 3.1. Laboratory of Mathematical Chemistry, University "Prof. Dr. Assen Zlatarov", Burgas, Bulgaria. Available at http://oasis-lmc.org.

NICNAS (2013). *Inventory Multi-tiered Assessment and Prioritisation (IMAP) Framework*. National Industrial Chemicals Notification and Assessment Scheme, Australian Government Department of Health, Sydney, Australia. Accessed 12 November 2013 at http://www.nicnas.gov.au.

OECD (2005). *SIDS Initial Assessment Report for SIAM 20*. Organisation for Economic Cooperation and Development, Paris, France. http://webnet.oecd.org.

UNECE (2009). *Globally Harmonised System of Classification and Labelling of Chemicals (GHS), 3rd Revised Edition*. United Nations Economic Commission for Europe, Geneva, Switzerland. Accessed 12 November 2013 at http://www.unece.org

UNEP (2012). *Historical Meetings Documentation*. United Nation Environment Programme, Nairobi, Kenya. http://montreal-protocol.org.

UNEP (2013a). *Proposed amendement to the Montreal Protocol submitted by Canada, Mexico and the United States of America*. United Nations Environment Programme, Bangkok, Thailand. at http://conf.montreal-protocol.org.

UNEP (2013b). *Proposed amendment to the Montreal Protocol submitted by the Federated States of Micronesia*. United Nations Environment Programme, Bangkok, Thailand. at http://conf.montreal-protocol.org.

UNFCCC (1998). *Kyoto Protocol to the United Nations Framework Convention on Climate Change*. United Nations Framework Convention on Climate Change, Bonn, Germany.

UNFCCC (2013). *Status of Ratification of the Kyoto Protocol*. United Nations Framework Convention on Climate Change, Bonn, Germany. Accessed 17 December 2013 at http://unfccc.int.

US EPA (2008). *Estimations Programs Interface (EPI) Suite^{TM} for Microsoft Windows®*, v 4.10. United States Environmental Protection Agency, Washington DC, USA. Available at http://www.epa.gov.

US EPA (2010). *Ozone Layer Protection Glossary*. United States Environmental Protection Agency, Washington DC, USA. Accessed 20 November 2013 at http://www.epa.gov.

US EPA (2012). *The ECOSAR (ECOlogical Structure Activity Relationship) Class Program for Microsoft Windows®*, v 1.11. United States Environmental Protection Agency, Washington DC, USA. Available at http://www.epa.gov.

US EPA (2013a). *Chemical Access Data Tool (CDAT)*. United States Environmental Protection Agency, Washington DC, USA. Accessed 12 November 2013 at http://java.epa.gov.

US EPA (2013b). *Clean Air Act: Title VI – Stratospheric Ozone Protection*. United States Environmental Protection Agency, Washington DC, USA. Accessed 12 November 2013 at http://www.epa.gov.

WMO (2011). Global Ozone Research and Monitoring Project - Report No. 52, *Scientific Assessment of Ozone Depletion: 2010*. World Meteorological Organization, Geneva, Switzerland. Accessed 20 November 2013 at http://www.wmo.int.

Last update 7 February 2014