Alkanes, C14-17, chloro-: Environment tier II assessment

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Preface

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

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

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

Stage One of the implementation of this framework, which lasted 4 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 3 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

Rationale

This Tier II assessment considers the environmental risks associated with industrial uses of a single substance which is a complex mixture of chlorinated linear alkanes. The substance is one member of a category of industrially important substances that are all complex mixtures of chlorinated linear alkanes. These substances and their discrete chemical constituents are more commonly described as ‘chlorinated paraffins’ and this terminology is also used in this assessment.

Substances in the category of industrially important chlorinated paraffins are each composed of large numbers of chlorinated paraffin congeners. The substance under assessment is composed of congeners which have chains of 14 to 17 carbon atoms. These congeners are considered to have carbon atom chains of intermediate length with respect to other chlorinated paraffins and they are collectively described as medium chain chlorinated paraffins (MCCPs). The other major sub-divisions in chain length are the short chain chlorinated paraffins (SCCPs), in which congeners have chains of 10 to 13 carbon atoms; long chain chlorinated paraffins (LCCPs), where congeners have chains of 18 to 20 carbon atoms; and very long chain chlorinated paraffins (vLCCPs), where the constituent congeners have chains of more than 20 carbon atoms.

Chlorinated paraffins have had significant industrial uses since the 1930s and the current global production volumes of some substances in this category are very large. They have become widely dispersed environmental contaminants and there are concerns regarding the environmental persistence, bioaccumulation potential and toxicity of some chlorinated paraffins. These concerns recently culminated in the listing of SCCPs with greater than 48% by weight of chlorine as Persistent Organic Pollutants (POPs) under Annex A (Elimination) of the *Stockholm Convention on Persistent Organic Pollutants* (the Stockholm Convention). This listing together with regulatory controls previously implemented in multiple countries has led to significant and evolving international restrictions on the manufacture and use of SCCPs. Global restrictions on this sub-category of chlorinated paraffins are expected to result in their eventual replacement in diverse industrial applications by other chemicals, including MCCPs.

This assessment will evaluate information currently available on the environmental fate and effects of medium chain chlorinated paraffins and consider whether industrial uses of these chemicals in Australia are of concern for the environment. This assessment also serves as reference information for other members of the chlorinated paraffins category which contain MCCPs and are listed on the Inventory.

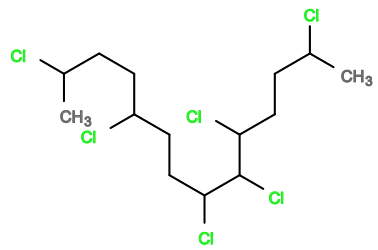
Chemical Identity

The chemical identified as alkanes, $C_{14\text{-}17}$, chloro- by the Chemical Abstracts Service (CAS) is an unknown or variable composition, a complex product of a chemical reaction, or a biological material (UVCB) substance. This chemical substance name and the associated CAS Registry Number (85535-85-9) are generally used for mixtures of chlorinated paraffins where MCCPs predominate (Danish Ministry of the Environment, 2014). The chlorine content of this substance is not specified in the chemical substance name; however, technical mixtures of MCCPs with industrial uses typically have a chlorine atom content in the range from 40% to 60% by weight (ECB, 2008).

This substance is a complex and variable mixture of medium chain chlorinated paraffin congeners and it, therefore, does not have a unique chemical identity. A more relevant consideration for the assessment of industrial uses of this substance (and other chlorinated paraffin UVCBs) are the chemical identities of the main congener groups that are present in technical mixtures. A congener group includes all congeners with the same chemical formula. For example, all MCCP congeners which have a linear tetradecane (fourteen carbon atom) chain substituted with six chlorine atoms belong to the hexachlorotetradecane (or $C_{14}H_{24}Cl_6$) congener group. The number of hydrogen atoms in the formula for a congener group can be omitted because it is specified by the number of carbon and chlorine atoms. Hence, the simplified formula, $C_{14}Cl_6$, is used to denote the group of hexachlorotetradecane congeners. This simplified notation for chlorinated paraffin congener groups is used throughout the following assessment.

Congeners in the $C_{14}Cl_6$ group have a chlorine atom content of 52.5% by weight and they constitute one of the main component congener groups typically present in technical MCCPs. The other main components are the $C_{14}Cl_5$ (47.8% chlorine), $C_{15}Cl_5$ (46.1% chlorine), and $C_{15}Cl_6$ (50.8% chlorine) congener groups. There are also minor quantities of the $C_{16}Cl_6$ (49.1% chlorine) and $C_{16}Cl_7$ (53.1%) congener groups typically present. However, it should be noted that the distribution of congener groups in technical MCCPs is variable and is ultimately determined by the manufacturing process and by the functional requirements for their various uses in products and articles (Strack, et al., 2012; Zitko, 1980). Congeners with branched carbon chains have lower stability in use and therefore MCCPs are generally produced with minimal quantities of branched chain congeners (Strack, et al., 2012).

All congener groups are mixtures of isomers. Isomerism in chlorinated paraffins occurs because chlorine atom substituents can be arranged in different ways along an alkane chain and because secondary carbon atoms with a single chlorine atom substituent are, in most instances, asymmetric. In the case of the $C_{14}Cl_6$ congener group, there are 1519 different ways to arrange six chlorine atoms along the tetradecane chain, assuming that there is only one chlorine atom substituent on every chlorinated carbon atom (Shojania, 1999; Tomy, 2010). For every one of these different arrangement of chlorine atoms, there are multiple stereoisomers, each of which has a unique sequence of asymmetric carbon atoms. An example structure is provided below of the arrangement of chlorine atoms along a tetradecane chain that is common to a set of 64 stereoisomers in the $C_{14}Cl_6$ congener group:

Synonyms	medium chain chlorinated paraffins (MCCPs) $C_{14\text{-}17}$ chloroalkanes
Example Structural Formula	

Molecular Formula	$C_{14}H_{24}Cl_6$
Molecular Weight (g/mol)	405.06
SMILES	C(Cl)(C(Cl)C(Cl)CCC(Cl)CCC(C)Cl)CCC(C)Cl

Physical and Chemical Properties

There is very little experimental physical and chemical property data available for MCCP congeners. A limited set of experimental data was identified for the properties of the monochlorotetradecane constitutional isomer, 1-chlorotetradecane (myristyl chloride; CAS RN 2425-54-9), which is tabulated below (US EPA, 2008). Standard quantitative structure-property relationships (QSPR) were used to estimate values for the water solubility and octanol-water partitioning coefficient (K_{ow}) of this discrete chemical (US EPA, 2008). The same suite of QSPRs was used to obtain indicative chemical property information for congeners in the $C_{14}Cl_6$ group based on the example structure provided in the Chemical Identity section:

Chemical	1-chlorotetradecane	2,5,6,7,10,13-hexachlorotetradecane
Physical Form	liquid	-
Melting Point	4.9°C (exp.)	73.7°C (calc.)
Boiling Point	292°C (exp.)	371.3°C (calc.)
Vapour Pressure	0.097 Pa at 25°C (exp.)	0.002 Pa at 25°C (calc.)
Water Solubility	0.012 mg/L at 25°C (calc.)	0.0002 mg/L at 25°C (calc.)
Ionisable in the Environment?	no	no
log K_{ow}	7.47 (calc.)	8.30 (calc.)

The vapour pressure of 1-chlorotetradecane at 25°C indicates that congeners with a low level of chlorination will be moderately volatile under ambient conditions. However, based on the calculated volatility for the example hexachlorotetradecane, highly

chlorinated congeners that predominate in technical MCCPs are only slightly volatile under the same conditions. The very large ratios for partitioning into octanol from water and the low water solubility values calculated for both 1-chlorotetradecane and 2,5,6,7,10,13-hexachlorotetradecane indicate that all MCCPs are very hydrophobic chemicals that are only very slightly soluble in water.

The chemical reactivity of MCCPs is low under ambient conditions, but they do degrade to release hydrochloric acid at elevated temperatures (Strack, et al., 2012). This reactivity is a functional requirement for several major industrial uses of MCCPs, but it can be modified by the addition of a range of different chemical stabilisers to technical mixtures. Stabilisers are also typically added to technical mixtures to improve their storage stability as accelerated degradation of MCCPs occurs under ambient conditions in the presence of impurities such as hydrochloric acid (Strack, et al., 2012). It is noted that most of the experimental data available for MCCPs have been obtained with stabilised technical mixtures as the test substance. The potential influence of additives and impurities on the relevance and reliability of test data obtained with technical MCCPs has been taken into consideration in this assessment.

Import, Manufacture and Use

Australia

Chlorinated paraffins are currently manufactured in Australia (Ixom, 2019a; NPI, 2019). Available safety data sheet information indicates that these chlorinated paraffins include technical $C_{14\text{-}17}$ chloroalkanes containing between 45% and 65% chlorine (Ixom, 2019b). Recommended uses for these technical MCCPs include as a secondary plasticising flame retardant in polyvinyl chloride (PVC), as a plasticiser in paint, and as an ingredient in hot melt adhesives for the building and construction industry (Ixom, 2019b).

Historical introduction data available to NICNAS indicates that $C_{14\text{-}17}$ chloroalkanes was manufactured at greater than 1000 tonnes per year in Australia in 1999 (NICNAS, 2001). The total annual introduction volumes as published in the 2002 and 2006 High Volume Industrial Chemicals Lists were between 1000 and 9999 tonnes (NICNAS, 2002; 2006).

MCCPs were reported to be used in metalworking fluids in Australia (NICNAS, 2004). The size of this market in 2002 was estimated to be approximately 475 tonnes per year combined for MCCPs and LCCPs. Metalworking fluids containing MCCPs are currently available in Australia (Sutton Tools, 2016).

International

Chlorinated paraffins are manufactured in multiple countries and the cumulative global production volume of total chlorinated paraffins is very large (UNEP, 2016b). The majority of the global production of chlorinated paraffins currently occurs in China, where the aggregate production volume in 2013 was 1.05 million tonnes (van Mourik, et al., 2016). The available production data does not include specific information on the production of MCCPs because chlorinated paraffins produced in China are differentiated based on their chlorine content rather than by the carbon chain lengths of their constituent congeners. Nevertheless, MCCPs are known to be major components of the technical chlorinated paraffins most commonly produced in China (Li, et al., 2018). In the European Economic Area, 10 000–100 000 tonnes of $C_{14\text{-}17}$ chloroalkanes is manufactured and/or imported annually (ECHA, 2019a).

The highest volume uses for MCCPs are as secondary plasticisers and flame retardants in flexible PVC products, and as extreme pressure lubricants in metalworking fluids (Strack, et al., 2012). The relative importance of these two main industrial uses for MCCPs differs by region. In the United States of America (USA), 74% of the production volume of $C_{14\text{-}17}$ chloroalkanes is used as a lubricant in metalworking fluid and 17% is used as a flame retardant/plasticiser in PVC resins (US EPA, 2015b). In the European Union (EU), the major uses for MCCPs are as a plasticiser/flame retardant in PVC and rubber articles and in products such as paints, coatings, adhesives, and sealants. In 2006, 16% of the volume of MCCPs used in the EU was for applications in metalworking fluids (Danish Ministry of the Environment, 2014).

Importation of MCCPs in articles accounts for the majority of the annual volume of these substances imported into some countries. For example, in Norway in 2009 it is estimated that 205 to 409 tonnes of MCCPs was imported in PVC articles (e.g., floor and wall coverings, and cables) and rubber articles (e.g. conveyor belt rubber), compared with imports of 78 tonnes of

MCCPs in the form of chemicals for use in products (e.g. insulation and sealant compounds, and glues) (Danish Ministry of the Environment, 2014; The Norwegian Ministry of the Environment, 2010). A later analysis of imports of MCCPs into Denmark also concluded that the majority of these substances are imported into that country in articles, especially plasticised PVC articles such as electrical cables (Danish Ministry of the Environment, 2014; The Norwegian Ministry of the Environment, 2010).

Environmental Regulatory Status

Australia

The use of this substance is not subject to any specific national environmental regulations.

The substance is listed on the Australian Hazardous Chemical Information System (HCIS) as hazardous to the aquatic environment (acute) – category 1, and hazardous to the aquatic environment (chronic) – category 1 (Safe Work Australia, 2018).

United Nations

The substance and MCCPs generally are not currently identified as Persistent Organic Pollutants (UNEP, 2001), ozone depleting substances (UNEP, 1987), or hazardous substances for the purpose of international trade (UNEP & FAO, 1998).

OECD

The substance was listed on the 2007 OECD list of high production volume (HPV) chemicals (OECD, 2017). It was sponsored for assessment by the United Kingdom under the 10th Screening Information Dataset (SIDS) Initial Assessment Meeting (SIAM 10) (OECD, 2012a), and a follow-up initial assessment profile was published based on additional information available at the 19th SIDS SIAM (SIAM 19) (OECD, 2012b). The SIAM 19 initial assessment profile noted the conclusions made by the European Union Risk Assessment program assessment of this substance, that risk reduction measures were needed for the production and use of MCCPs in PVC, other plastics and rubber, paints, metal cutting/working fluids, leather fat liquors and carbonless copy paper, and recommended further that an environmental exposure assessment be conducted to determine the need for similar measures for countries outside of Europe (OECD, 2012b).

Canada

The substance is listed on the Canadian Domestic Substances List (DSL) (Environment and Climate Change Canada, 2019b). During the Categorization of the DSL, this substance was categorized as Persistent (P), Bioaccumulative (B), and Inherently Toxic to the Environment (iT_E) (Environment and Climate Change Canada, 2019a), and was therefore prioritised for further assessment.

An assessment was published in 1993, and a follow-up assessment was published in 2008 (Environment and Climate Change Canada, 2018b). The 2008 assessment concluded that chlorinated paraffins up to 20 carbons in length are both persistent and bioaccumulative, and may be entering the environment in concentrations that may have an immediate or long-term effect on the environment (Environment and Climate Change Canada, 2008). Based on these conclusions, chlorinated paraffins including this substance were listed under Schedule 1 (List of Toxic Substances) of the *Canadian Environmental Protection Act 1999* (CEPA) (Environment and Climate Change Canada, 2018a).

Chlorinated paraffins up to 20 carbon atoms in length were also recommended to be added to the Virtual Elimination List, which would restrict the quantity or concentration of the substance that may be released into the environment (Environment and Climate Change Canada, 2018a).

European Union

The substance is registered under the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) legislation (ECHA, 2019b). There are no current restrictions on its use in the EU. A proposal for restriction of the use of this substance in electronics under the Restriction of Hazardous Substances (RoHS) directive was submitted to the European Commission in 2018 (KEMI, 2018).

The substance was prioritised for assessment under the superceded Existing Substances Regulation (ESR), with a risk assessment report published in 2005 followed by an addendum published in 2007 (ECB, 2005; 2007). This assessment process was continued under transitional substance evaluation measures contained in the REACH legislation after its implementation in 2008 (ECHA, 2009). The Annex XV report under these transitional measures indicated that a proposed restriction for the use of MCCPs in leather fat liquors would be taken forward under the REACH process (ECHA, 2008). A PBT/vPvB assessment conducted under the transitional measures concluded that MCCPs contain components that potentially meet the Annex XIII criteria for a PBT substance in the environment, but that a definitive conclusion could not be drawn based on the information available at the time (ECHA, 2010a; 2010b).

The assessment process continued under the Community Rolling Action Plan (CoRAP) with the UK environment agency as the competent authority (ECHA, 2012). Under this process, registrants of MCCPs were required to supply information related to environmental exposure scenarios and the PBT characteristics of this substance by a final deadline of 9 September 2018 (ECHA, 2014; 2015) . This assessment process has been completed, with the final substance evaluation report concluding that MCCPs meet the Annex III criteria for a PBT substance, as well as the very persistent and very bioaccumulative (vPvB) criteria (ECHA, 2019c). The development of Annex XV dossiers for substance of very high concern (SVHC) identification and restriction of this substance was recommended (ECHA, 2019d).

Norway

The Norwegian Government has established national targets for eliminating or substantially reducing the release of priority hazardous substances by 2010 with a view to eliminating them by 2020. MCCPs were listed on the Priority List of hazardous substances (The Norwegian Ministry of the Environment, 2010). The main sources for MCCP emissions in Norway are products imported from the EU and other countries (The Norwegian Ministry of the Environment, 2010). The Norwegian Government has proposed to regulate the production, import, export and trade of consumer products containing ≥ 0.1% by weight MCCPs apart from those which have special fire safety requirements (The Norwegian Ministry of the Environment, 2010).

United States of America

The US Environmental Protection Agency (US EPA) identified CPs (SCCPs and MCCPs) for action plan development based on their presence in humans and PBT characteristics (US EPA, 2009).

An assessment of ‘Alkanes, C_{14-17}, chloro (MCCPs; 40–60 wt% Cl)’ was conducted under EPA’s TSCA Section 5 New Chemicals Review Program beginning in 2012 (US EPA, 2018b). Companies were required to submit premanufacture notifications (PMNs) for all chlorinated paraffins produced domestically or imported. An additional request for any new information was issued in 2015 (US EPA, 2018b). Based on these assessments it was concluded that MCCPs and LCCPs “may be released to the environment at levels at or above estimated concentrations of MCCP and LCCP congener groups that may present an unreasonable risk following acute and chronic exposures to aquatic organisms” (US EPA, 2015b). It was also concluded that the evaluated MCCPs may be very persistent and very bioaccumulative. The section 5(e) consent order published as a result of these PMN submissions required introducers to submit new toxicity testing on specified MCCP congener groups within 5 years, and limited the uses of MCCPs to those named in the consent order, including use as a flame retardant and plasticiser in PVC and in metalworking fluids (EPA, 2017).

Significant New Use Rules (SNUR) were proposed for these substances in August 2018 (US EPA, 2018a). Final rules have not yet been issued.

Environmental Exposure

Industrial uses of the substance are expected to result in both diffuse and point source emissions of MCCPs into the environment. MCCPs do not occur naturally.

Disposal of metalworking fluids containing MCCPs and facility wash-down from MCCP manufacturing and formulation activities may lead to significant releases of MCCPs to the aquatic environment (Environment and Climate Change Canada, 2008; OECD, 2011a; UNEP, 2016a). An environmental exposure assessment for SCCPs used in metalworking fluids in Australia between 1998 and 2002 estimated that as a worst-case scenario 18% of SCCPs used in cutting fluid would be released to sewers (NICNAS, 2004). This release scenario is expected to also apply to MCCPs used in metalworking fluids.

A major use of MCCPs is as plasticisers and flame retardants in flexible PVC, paints and coatings, sealants and adhesives and other products and articles. A typical concentration for MCCPs in plasticised PVC is 15% by weight (ECHA, 2018), while reports of chlorinated paraffin use in paint ranges from 1–10% (Levine, 1970; Miller and Wolfe, 1979). Release of MCCPs may occur through abrasion, wear and volatilisation from these products and articles, which may result in diffuse environmental release or partitioning to indoor dust (OECD, 2011b). MCCPs have been detected in dust collected from offices, homes and non-residential buildings in Australia (He, et al., 2019; Wong, et al., 2017). MCCPs in household dust may be released to wastewater through cleaning and washing of fabrics and surfaces. At the end of their useful life, a significant proportion of articles containing MCCPs are likely to be disposed of to landfill.

The majority of the quantity of MCCPs entering sewage treatment plants (STP) is expected to partition to and be retained in biosolids. MCCPs may then be released to the environment as a result of the application of these biosolids to soil where they can be dispersed to other locations and environmental compartments by soil erosion, runoff, and through wind borne particulates and volatilization (US EPA, 2015b). This exposure scenario is relevant for this assessment because a significant proportion of biosolids produced in Australia are applied to agricultural land (ANZBP, 2017). In addition, a recent monitoring study has shown that MCCPs are present in sewage sludge from STPs in Australia (Brandsma, et al., 2017). Therefore, emission of MCCPs to soils is considered as part of this assessment.

Environmental Fate

Partitioning

MCCPs are expected to primarily partition to soil and sediment in the environment.

High estimated organic carbon-normalised adsorption coefficients (K_{oc}) for a 52% chlorinated MCCP mixture (log K_{oc} = 4.5–6.6) and for $C_{14\text{-}15}Cl_{5\text{-}8}$ congener groups (log K_{oc} = 5.2–5.4) indicate strong partitioning of MCCPs from water to soil and sediment. These K_{oc} values were estimated based on measured log K_{ow} values (Hilger, et al., 2011) according to the method used in the EU risk assessment (ECB, 2005). MCCPs will, therefore, have a strong tendency to partition from water to organic carbon in soil, sediment, and suspended particles. They are also expected to be immobile in soil.

The predicted Henry's Law constants for the most abundant C_{14} and C_{15} congener groups with five to eight chlorine atoms were calculated to be in the range of 10^{-12}–10^{-2} atm-m^3/mole by using bond and group estimates (US EPA, 2008). These low values would typically indicate that MCCPs with a high degree of chlorination are only very slightly volatile from water and moist soil. Nevertheless, MCCP congeners with 14 carbon atoms and six to nine chlorine atoms (53–63% chlorine) were detected in air samples from urban environments in China indicating that MCCP congeners with a high degree of chlorination can also partition to the air compartment (Li, et al., 2018).

Degradation

MCCPs persist in sediments under aerobic and anaerobic conditions. The persistence of MCCPs in soils is currently uncertain.

Abiotic degradation processes (hydrolysis and photolysis) are not expected to be significant dissipation pathways for MCCPs in the environment (US EPA, 2015b). MCCPs undergo thermal degradation into chlorinated olefins and hydrochloric acid at high temperatures as an aspect of their functional use as high-pressure lubricants in metal cutting/drilling processes (Schinkel, et al., 2018).

$C_{14\text{-}17}$ Chloroalkanes is not considered to be readily biodegradable, although some of the constituent C_{14} congeners may be readily biodegradable based on screening studies. One study conducted according to OECD Test Guideline (TG) 301D on a mixture of C_{14} congeners containing 45% chlorine found that this mixture could be considered readily biodegradable (ECHA, 2010b; REACH, 2020). After 28 days, 64% degradation was recorded, using a sewage sludge inoculant and a polyalkyloxylate

alkylphenol solubiliser. However, other studies conducted with C_{14-17} MCCP congeners with similar inoculants and solubilisers did not pass the ready biodegradation test within the test guidelines (ECHA, 2010b).

MCCPs are persistent in sediment under both aerobic and anaerobic conditions. In an aerobic degradation study conducted according to OECD TG 308 on a mixture of C_{14} congeners containing 50% chlorine, no biotransformation was observed after 120 days. The disappearance time 50 (DT50) was > 120 days under the test conditions (REACH, 2020). A study on chlorinated paraffins in Swedish sediment core samples dating from the 1930s to the present day quantified chlorinated paraffins with chain lengths from C_8 to C_{38}, indicating their persistence for several decades under anaerobic conditions once buried (Yuan, et al., 2017). Of the MCCP congeners detected, C_{14} and C_{15} congeners were the most abundant, reflecting the congener groups that often dominate in technical MCCP mixtures. MCCPs have also been detected in sediment cores in a number of other studies (Environment and Climate Change Canada, 2008; Iozza, et al., 2008 ; Muir, 2010 ; van Mourik, et al., 2016).

These findings are consistent with the established environmental persistence of SCCPs, a closely related group of chemicals. For SCCPs (C_{10-13}) containing 65% chlorine, the estimated half-lives in freshwater sediments and marine sediments under aerobic conditions are 1630 days and 450 days, respectively. There was little or no mineralization of the SCCP mixture under anaerobic conditions based on the results of this OECD TG 308 study (UNEP, 2015).

No studies have been identified that could be used to estimate half-lives of MCCP congeners in soil. Bacterial strains isolated from soil through enrichment cultures using *n*-hexadecane as the sole carbon source have been shown to be capable of degrading some MCCP congeners, although no strains were capable of growing with MCCPs as the sole carbon source (Omori, et al., 1987). The degradation mechanism was reported to proceed by initial oxidation of the terminal methyl group of a chlorinated paraffin chain, producing a chlorinated fatty acid, followed by iterative β-oxidation of the chlorinated fatty acid chain. However, some of the chlorinated fatty acid isomer products of this degradation pathway may not be amenable to further β-oxidation.

MCCPs are expected to partition to aerosols in the air compartment, which may shield them from vapour phase degradation mechanisms (van Mourik, et al., 2016). Vapour phase half-lives for MCCP congeners have been calculated to be in the range of 1–7 days based on rates of reaction with hydroxyl radicals (Glüge, et al., 2018). However, the relative importance of atmospheric oxidation of MCCPs by hydroxyl radicals to the degradation of these chemicals in the environment is currently uncertain. SCCPs are, however, considered to be persistent in the air compartment (UNEP, 2015).

Bioaccumulation

Some MCCP congener groups are highly bioaccumulative. The congener groups of highest apparent bioaccumulation potential are $C_{14}Cl_{5-8}$.

Some MCCP congeners have high bioconcentration potential. In a bioconcentration study, rainbow trout (*Oncorhynchus mykiss*) were exposed to 0.34 µg/L ^{14}C-labelled C_{14} congeners with a chlorination degree of 45% (~$C_{14}Cl_{4.5}$) in a flow-through system for 35 days followed by a depuration period of 42 days. The kinetic BCF value normalised to 5% lipid content was 4460 L/kg, or 14 600 L/kg after correction for rainbow trout growth (ECHA, 2010b). These BCF values significantly exceed the domestic categorisation threshold for bioaccumulation of ≥ 2000 L/kg (EPHC, 2009). A number of additional bioconcentration and bioaccumulation studies for MCCPs were evaluated by the European Chemicals Bureau/European Chemicals Agency, the US EPA and Environment and Climate Change Canada (ECB, 2005; 2007; 2008 ; ECHA, 2010b; Environment and Climate Change Canada, 2008; US EPA, 2015b). Several laboratory-based studies with common mussel, bleak, and rainbow trout exposed to MCCPs in freshwater and seawater systems relied on solvent-assisted exposure to these substances (US EPA, 2015b). In these studies, estimated BCF values varied between 32 and 2856 L/kg, but they did not adhere to OECD test guidelines due to use of acetone co-solvent and test substance concentrations above water solubility limits (US EPA, 2015b).

A lipid-normalised and growth-corrected biomagnification factor (BMF) of 0.468 was determined for a mixture of C_{14} congeners with 50% chlorine, based on a dietary bioaccumulation study conducted with rainbow trout according to OECD TG 305 (REACH, 2020). A growth-corrected depuration half-life of 108 days was determined, indicating very slow depuration kinetics in fish.

One field study quantified MCCPs in two freshwater food chains in the North American Great Lakes. This study derived high bioaccumulation factors (BAFs), a range of biomagnification factors (BMFs), and low trophic magnification factors (TMFs) for sums of MCCP congeners (ΣMCCPs) (Houde, et al., 2008). The highest concentrations of MCCPs were found in rainbow smelt and sculpin, two bottom-dwelling fish species, indicating that sediment may be a source of MCCP uptake.

Calculated bioaccumulation factors (log of the BAF when expressed in L/kg lipid) for fish ranged from 6.6 for lake trout (*Salvelinus namaycush*) to 7.3 for sculpin (*Cottus cognatus*), indicating high bioaccumulation potential of MCCPs (Houde, et al., 2008). A high lipid normalised biomagnification factor (BMF) of 8.7 was calculated for ΣMCCPs between slimy sculpin (*Cottus cognatus*) and its invertebrate prey, Diporeia (*Diporeia sp.*) in Lake Ontario. However, a lower BMF of 0.88 was calculated for the same two species in Lake Michigan, and BMFs of 0.11–0.94 were calculated for accumulation of ΣMCCPs from 3 prey fish species (alewife, rainbow smelt and sculpin) to lake trout in each freshwater food chain.

The same study calculated trophic magnification factors (TMFs) in the range of 0.06–0.36 for MCCP congeners in the invertebrates – forage fish – lake trout food webs from Lake Ontario (Houde, et al., 2008). The results of this study suggest that MCCP congeners have potential for bioaccumulation but low potential for biomagnification through trophic levels in these freshwater systems.

Zeng, et al. (2017) calculated a TMF of 4.79 for ΣMCCPs in a marine food web from Hong Kong waters, finding that MCCPs could enter benthic organisms from sediment and accumulate through trophic levels into marine mammal apex predators. MCCP congeners were detected in each of the 27 species of fish, crustacean and mollusc sampled (Zeng, et al., 2017). Biota-sediment accumulation factors (BSAFs) calculated for the crustacean and mollusc species ranged from 0.9–2.3, indicating that introduction of MCCPs into biota from sediment was occurring. BMFs between 1.4 and 58 were calculated for accumulation of ΣMCCPs from 15 prey fish species to two cetacean apex predator species (finless porpoise and Indo-Pacific humpback dolphin) (Zeng, et al., 2017), indicating significant biomagnification of MCCPs from prey to predator. A positive relationship between trophic level and lipid-normalised MCCP concentrations was found over multiple trophic levels, with the calculated TMF of 4.79 indicating high potential for bioaccumulation and trophic transfer of MCCPs in this marine food web.

The dominant MCCP congeners found in this study were in the $C_{14}Cl_{5\text{-}7}$ group. Approximately 35–54% of the MCCP congeners quantified in the sampled mollusc, crustacean and fish species were in the C_{14} group, while the average chlorination degree of all MCCPs was 49-53% (Zeng, et al., 2017). A comparatively higher fraction of C_{14} congeners was observed in the two cetacean predator species indicating that C_{14} congeners may have a greater bioaccumulation potential than $C_{15\text{-}17}$ congeners.

MCCPs have been detected at high concentrations in terrestrial species (Du, et al., 2018; Yuan, et al., 2019). As in previous studies, C_{14} congener groups were the most abundant. Normalised lipid weight concentrations of MCCPs in terrestrial species were frequently higher than those found in marine species, indicating that bioaccumulation in terrestrial species may also be of concern.

Transport

Some MCCP congeners undergo long-range transport.

MCCPs are globally distributed pollutants. They are found at low levels (4–140 picograms per cubic metre (pg/m^3)) in air from remote areas such as the Arctic and Antarctic (Glüge, et al., 2018; Ma, et al., 2014; van Mourik, et al., 2016). Ma, et al. (2014) concluded that long-range atmospheric transport was a major input route of MCCPs to Antarctica, and that sorption to aerosol organic matter may have a significant effect on the transfer and partitioning of MCCPs in this region.

CPs including MCCPs have been measured in multiple marine Arctic species including top predators (polar bear and ringed seal) indicating widespread exposure to these substances in the Arctic marine environment (Norwegian Climate and Pollution Agency, 2013; Reth, et al., 2006; Saborido Basconcillo, et al., 2015; UNEP, 2015). The dominant MCCP congener groups ($C_{14}Cl_{6\text{-}7}$) have been measured in biota from the European and Canadian Arctic regions which might be a result of transport of CPs through the atmosphere and/or in birds (Reth, et al., 2006; Saborido Basconcillo, et al., 2015).

Predicted Environmental Concentration (PEC)

Environmental concentrations of MCCPs were estimated from available domestic and international monitoring data for MCCP congeners in wastewater effluents, biosolids and soils. Domestic monitoring data indicated MCCPs were present in sewage sludge collected from STPs in Australia with a maximum measured concentration of 3645 nanograms per gram dry weight (ng/g dw), and that $C_{14}Cl_{6\text{-}8}$ MCCPs were the most abundant congener groups.

Chlorinated paraffins were quantified in sewage sludge samples from fifteen STPs across Australia (Brandsma, et al., 2017). Total MCCP concentrations ranged from 542–3645 ng/g dw, with the average chlorination degree of each sampling site in the

range of 53.5% to 57.5%. The C_{14} and C_{15} congeners were the most abundant. These concentrations and congener profiles are comparable to the concentrations and congener composition of MCCPs in STP sludge samples from Swedish, Czech, and Swiss sewage treatment plants taken between 2004 and 2010 (Brandsma, et al., 2017). MCCPs in sludge may be released to the environment by application of biosolids to soil (US EPA, 2015a).

The calculated total MCCP concentration in soil amended with biosolids is in the range of 4–28 µg/kg based on the measured sewage sludge concentrations for Australia indicated above, typical biosolids application rates (EPHC, 2009; SAEPA, 1997), and a soil bulk density of 1300 kilograms per cubic metre (Langdon, et al., 2010). A maximum concentration of 112 µg/kg was calculated based on maximum permissible application rates and maximum measured sludge concentration (Langdon, et al., 2010). These calculated values are comparable with measured MCCP soil concentrations in Europe, China and South Africa (Glüge, et al., 2018). These estimations do not take into account the potential persistence of these substances in soil, which may result in much higher soil concentrations from cumulative applications of biosolids.

MCCPs are expected to partition to sediments in aquatic systems. No recent domestic monitoring data for MCCPs in sediments was identified. Sediment samples in non-industrial regions in Canada, Europe and South Africa had measured ΣMCCP concentrations of 1–403 ng/g dw (Glüge, et al., 2018). A non-peer reviewed historical record indicates elevated concentrations of C_{14} and C_{15} congeners (385 to 6747 µg/kg dw), and ΣMCCP (16 403 µg/kg dw) in contaminated sediments collected from an industrial area in Australia in 2001 (Kemmlein, et al., 2002). However, this study does not provide the chlorination degree of detected CPs in sediments and may not be representative of current MCCP concentrations in Australia.

No recent domestic environmental monitoring data for MCCPs were identified for surface waters in Australia. Measured concentrations of MCCPs in international surface waters away from point release sources are generally low, with filtered Lake Ontario water containing 1 picogram per litre (pg/L) and stormwater from Oslo in the range of 15–130 ng/L (Glüge, et al., 2018).

No data were identified for levels of MCCPs in the air in Australia. MCCP levels in the air compartment are expected to be elevated in locations in close proximity to point emission sources such as wastewater treatment plants and in urban settings (Gillett, et al., 2017; van Mourik, et al., 2016).

Environmental Effects

Effects on Aquatic Life

Standard short- and long-term aquatic toxicity tests available for MCCP technical mixtures generally indicate that these substances cause toxic effects in aquatic invertebrates at very low exposure concentrations within the range of their reported water solubility limits. There is also evidence of potential narcotic effects at environmentally relevant MCCP body burdens in fish. The toxicity data presented below were obtained from government reports (ECB, 2005; US EPA, 2015b) and the peer-reviewed scientific literature. Multiple toxicity tests on MCCP mixtures have been described in study reports which were not available for this assessment but have been reviewed by experts in other regulatory agencies.

The majority of toxicity studies were conducted with MCCP $C_{14\text{-}17,}$ 52% chlorine as the test substance. In many studies, the MCCP test substance was mixed with a known amount of radiolabelled n-pentadecane-8-^{14}C, 51% chlorine. Radiochemical analysis of the test solution was then used to estimate the total MCCP concentration (ECB, 2005). Some test substances contained a small amount of stabiliser (0.3% epoxidised soybean oil), which is not expected to contribute significantly to the overall toxicity of the mixture.

The exact chemical composition of tested MCCP mixtures is unknown. MCCP $C_{14\text{-}17,}$ 52% chlorine mixtures are expected to be dominated by C_{14} and C_{15} congeners with approximately six chlorine atoms per molecule. These test mixtures therefore have similar chain lengths but slightly lower chlorination degrees compared to MCCP congener groups found in sewage sludge collected in Australia, which contained 53.5–57.5% chlorine. While further information is required to understand the contribution of different congener groups to overall toxicity effects of complex mixtures of MCCPs, a review of the available ecotoxicity and mammalian toxicity of chlorinated paraffins concluded that they have a common mode of action and effects from simultaneous exposure to chlorinated paraffins with different chain lengths are likely to be described by the concentration addition method (UNEP, 2011).

Acute toxicity

Acute toxicity studies indicate that both MCCP technical mixtures and MCCP congeners are not toxic to fish (bleak, golden orfe, rainbow trout) in solvent assisted static, semi-static and flow-through systems at concentrations below their water solubility limits (ECB, 2005).

MCCP technical mixtures and MCCP congeners are acutely toxic to aquatic invertebrates (ECB, 2005). A 48 h EC50 of 0.0059 mg/L (5.9 µg/L) for water fleas (*Daphnia magna*) was determined based on a test conducted according to OECD TG 202 with MCCP $C_{14-17,}$ 52% chlorine under static conditions (ECB, 2005; Thompson, et al., 1996). Consistent with some other aquatic toxicity studies on MCCPs, this study used acetone as a co-solvent to solubilise the test substance due to its low water solubility and potential to adsorb to the surfaces of the experimental vessels.

Studies that did not use co-solvents or dispersants to solubilise the MCCP test substances often used stock solutions that had been prepared with an excess of the test substance before filtration to remove undissolved material (ECB, 2005). In tests with these stock solutions, the endpoint values varied depending on the stock solution, with EC25 values from 339–423 µg/L, and EC50 values of 37 and > 350 µg/L (ECB, 2005; Frank, 1993; Frank and Steinhäuser, 1994; Thompson, 2004). As an excess of the MCCP test substance was generally used when preparing the stock solutions, the more water-soluble congener groups in the mixture were likely to be overrepresented in the prepared test solutions.

MCCP $C_{14-17,}$ 52% chlorine showed no effects on respiration of microorganisms in activated sludge based on a 3 h respiration inhibition test (ECB, 2005).

Chronic toxicity

The following no-observed-effect concentration (NOEC) and LC50 values presented below are for MCCP $C_{14-17,}$ 52% chlorine as the test substance (ECB, 2005; Thompson, et al., 1997b):

Taxon	Endpoint	Method
Invertebrates	21 d NOEC = 0.01 mg/L (reproduction) 21 d LC50 = 0.025 mg/L (mortality)	*Daphnia magna* OECD TG 202 Semi-static Acetone co-solvent

The 21 d test with *Daphnia magna* summarised in the table above showed significant decreases in the number of live offspring and the mean length of the parent animals at measured exposure concentrations at or above 0.018 mg/L (ECB, 2005; Thompson, et al., 1997b).

Mortality endpoint values from the 21 d *Daphnia magna* study described in the table above also included a 4 d EC50 of 0.046 mg/L, which is significantly higher than the acute 48 h EC50 of 0.0059 mg/L (ECB, 2005; Thompson, et al., 1997b). One possible reason for this is that the water fleas were fed during the 21 d study, but not in the 48 h study; in a preliminary investigation into this at two MCCP exposure concentrations with *Daphnia magna*, all 10 unfed test organisms had died after 3 days, while after 9 days only one of the 10 fed organisms had died (ECB, 2005). The fed organisms had an advantage either through better nutritional status, or indirectly because the test substance adsorbed to the food and thereby reduced exposure to MCCPs in the aqueous phase.

A chronic algal toxicity test was conducted on green algae (*Raphidocelis subcapitata*, formerly *Selenastrum capricornutum*) according to OECD TG 201 (ECB, 2005; Thompson, et al., 1997a), which determined a maximum growth inhibition of 18% and a 72 h NOEC of 0.1 mg/L. At concentrations above the NOEC, growth inhibition was not dose-dependent, which may indicate that the effect was caused by undissolved test substance rather than substance toxicity.

A dietary exposure study was conducted with several well-defined CP groups in juvenile rainbow trout, which showed potential narcotic toxic effects with a C_{14}, 55% chlorine MCCP test substance (93% $C_{14}Cl_{6-8}$ congeners) (Cooley, et al., 2001). Fish exposed to 29 µg/g of C_{14}, 55% chlorine MCCPs in food for 21 days had behavioural alterations including a loss of startle

response and slow feeding. Dark skin colouration developed in 3 out of 10 trout from this exposure group. At an exposure concentration of 78 µg/g MCCPs in food, behavioural alterations included a loss of startle response, cessation of feeding by day 3 of exposure, and dwelling near the bottom of the tank with little activity from day 7, and dark skin colouration observed in 9 out of 10 trout. Histopathological analysis of the livers of 5 trout from the 29 µg/g exposure group after 21 days showed moderate to severe glycogen and lipid depletion in each trout, with one trout developing severe inflammation with moderate hepatocyte necrosis, minor inflammation and hepatocyte necrosis seen in another trout, and minor hepatocyte necrosis in a third trout. Mean trout weight and liver somatic indices were unaffected. The whole body concentration of C_{14}, 55% chlorine in this exposure group was 1.3 µg/g ww.

The measured fish body burdens that elicit potential narcotic effects are close to some measured total MCCP concentrations in biota. In a biomonitoring study in Lake Ontario, the maximum measured concentrations in fish were 0.109 µg/g ww (Houde, et al., 2008). However, uncertainties remain as to the relevance of this narrow C_{14} MCCP group endpoint to the toxic effects of the much broader MCCP congener group distribution detected in biota.

Effects on Sediment Life

Based on the available information, MCCPs have low potential to cause toxic effects in sediment-dwelling organisms.

Long-term exposure tests in sediment-water systems using spiked sediments have been conducted with MCCP $C_{14\text{-}17,}$ 52% chlorine as the test substance to evaluate the effects of MCCPs on sediment-dwelling organisms (ECB, 2005; Phipps, et al., 1993; Thompson, et al., 2001a; 2001b ; Thompson, et al., 2002):

Taxon	Endpoint	Method
Invertebrates	28 d NOEC = 3800 mg/kg dry weight (dw)	*Chironomus riparius* (freshwater midge) Static OECD TG 218 (Draft guideline 2000)
	28 d NOEC = 130 mg/kg dw	*Lumbriculus variegatus* (oligochaete) Static Phipps et al study (1993)
	28 d NOEC = 130 mg/kg dw	*Hyalella azteca* (amphipod) Semi-static OECD TG 218 (Draft guideline 2001)

Effects on Terrestrial Life

Based on the available information, MCCPs have low potential to cause toxic effects in terrestrial organisms.

In three tests below, the organisms were exposed to MCCP $C_{14\text{-}17,}$ 52% chlorine in soil (ECB, 2005):

Taxon	Endpoint	Method
Invertebrates	56 d NOEC = 280 mg/kg dw	*Eisenia fetida* (earthworm) OECD TG 222 (Draft guideline 2000) and OECD TG 207
Plants	28 d NOEC ≥ 5000 mg/kg dw	*Triticum aestivum* (wheat) *Brassica napus* (oilseed rape) *Phaseolus aureus* (mung bean) OECD TG 208
Soil microorganisms	28 d NOEC ≥ 400 mg/kg dw	Nitrogen transformation test OECD TG 216

Air breathing animals may be exposed to MCCPs through dietary exposure pathways. The toxicity of MCCPs to humans and model animals (rats, mice, dogs, rabbits) was reviewed in the Human Health Tier II assessment of MCCPs (NICNAS, 2018). Based on the available data it was concluded that MCCPs have low acute toxicity. A number of repeated dose oral toxicity studies in animals indicate that the main target organs for MCCPs are the liver, thyroid and kidney; however, the effect concentrations were generally high.

Predicted No-Effect Concentration (PNEC)

The main congener groups in $C_{14\text{-}17}$ chloroalkanes are highly bioaccumulative and environmentally persistent. These two hazard characteristics combined have the potential to result in a range of long term effects on aquatic life exposed to this chemical which cannot be readily identified through standard toxicity 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 this substance.

Categorisation of Environmental Hazard

MCCP congener groups categorised as persistent, bioaccumulative and toxic comprise a significant fraction of $C_{14\text{-}17}$ chloroalkanes. These MCCP congener groups ($C_{14}Cl_{5\text{-}8}$ followed by $C_{15}Cl_{5\text{-}8}$) dominate in commercial MCCP products and were frequently detected in archived and recent collected sediments, soils and biota. Therefore, alkanes, $C_{14\text{-}17}$, chloro- has been identified as a PBT substance.

The categorisation of the environmental hazards of $C_{14\text{-}17}$ chloroalkanes according to domestic environmental hazard thresholds is presented below (EPHC, 2009; NICNAS, 2017):

Persistence

Persistent (P). Based on measurements of MCCP congeners ($C_{14-15}Cl_{5-8}$) in sediments accumulated over several decades at multiple locations and a measured DT50 of greater than 120 days for C_{14} MCCP congeners in aerobic sediment, the substance is categorised as Persistent.

Bioaccumulation

Bioaccumulative (B). Based on a TMF of 4.79 for total MCCPs in a marine food web, measured field BMFs > 1, and measured BCFs and BAFs greater than the domestic categorisation threshold of 2000 L/kg, the substance is categorised as Bioaccumulative.

Toxicity

Toxic (T). Based on measured acute and chronic toxicity values for MCCP $C_{14-17,}$ 52% chlorine less than 0.1 mg/L, the substance is categorised as Toxic.

Summary

Alkanes, C_{14-17}, chloro-is categorised as:

- P
- B
- T

Risk Characterisation

C_{14-17} Chloroalkanes contains high proportions of congener groups that are persistent, bioaccumulative, and toxic, and the substance has, therefore, also been identified as a PBT substance. Due to their persistence, PBT substances have the potential to become widely dispersed environmental contaminants. Once in the environment, persistent substances that are also bioaccumulative pose an increased risk of accumulating in exposed organisms and of causing adverse effects. They may also biomagnify through the food chain resulting in very high internal concentrations, especially in top predators. Importantly, it is difficult or impossible to mitigate the risk of adverse effects of PBT substances once they have been released. As a result, these substances are considered to be of high concern for the environment.

Persistent Organic Pollutants (POPs) are chemicals that are very persistent, very bioaccumulative, toxic, and have potential to undergo long-range transport. Australia is a signatory to the Stockholm Convention, which identifies POPs and aims to reduce or eliminate the environmental release of POP substances. It is noted that based on the environmental hazard data considered for this assessment, alkanes, C_{14-17}, chloro- may meet the Annex D screening criteria for POPs under the Stockholm Convention.

MCCP congener groups with PBT characteristics are frequently identified as major components of all MCCPs measured in the environment, including in sediments and biota. Although no contemporary monitoring data for these contaminants in the Australian environment have been identified, they have been measured in indoor dust and in sewage sludge taken from multiple STPs around Australia in recent studies. These measurements establish the potential for release of PBT MCCPs onto agricultural land in Australia through the land application of biosolids as soil improvers. In addition, MCCPs are manufactured in Australia and this may result in localised environmental release from these industrial sites.

There is a significant weight of evidence to support the finding that the major MCCP congener groups in technical C_{14-17} chloroalkanes have the characteristics of PBT chemicals. However, given the complex nature of the substance, some international regulatory agencies have required industry to conduct further studies on this substance with the aim of establishing the PBT characteristics of the congener groups of highest potential concern. These studies will use test substances that are not technical mixtures, but are groups of defined carbon chain length and chlorination degree (e.g., C_{14} with 30% or 56% chlorine). The results of these studies may help refine the characterisation of the environmental hazards of MCCPs for regulatory purposes.

Key Findings

The substance under assessment is a complex and variable mixture of medium chain chlorinated paraffins that is used in a wide range of chemical products and manufactured articles. Although the cumulative global production volume for this substance has not been established, it is known to be manufactured, transported and used in very large volumes globally. The substance has been introduced into Australia in high volumes in the past. The substance is currently being manufactured in Australia.

The known industrial uses for the substance in Australia are similar to typical uses that have been reported internationally. These include use as an extreme pressure additive in lubricants for metalworking fluids and use as a secondary plasticiser in PVC plastics. The quantities of the substance that are used for these different applications in Australia are unknown.

This assessment has established that $C_{14\text{-}17}$ chloroalkanes is a PBT substance according to domestic environmental hazard criteria. Therefore, it is considered to be a high concern substance. The review of environmental information conducted for this assessment also suggests that some MCCP congener groups may meet the Annex D screening criteria for Persistent Organic Pollutants under the Stockholm Convention.

The hazardous environmental characteristics of some MCCP congener groups identified in this assessment are of concern because recent chemical monitoring studies conducted in Australia have identified MCCPs as the dominant category of chlorinated paraffins in sludge from multiple sewage treatment plants across Australia. These research findings establish the potential for widespread emission of these PBT chemicals into the environment in Australia. Further consideration of the potential impacts of these emissions is limited by a lack of chemical monitoring data for MCCPs in the wider environment and insufficient information regarding the scale of current industrial uses in Australia.

Recommendations

Further evaluation of the environmental risks resulting from industrial uses of $C_{14\text{-}17}$ chloroalkanes in Australia is recommended. Any further evaluation of this substance will focus on reducing uncertainties regarding the environmental exposure resulting from industrial uses of substances containing MCCPs in Australia, the persistence of MCCPs in the soil compartment, and whether MCCPs meet the Annex D criteria of the *Stockholm Convention on Persistent Organic Pollutants*. A reduction in uncertainty with respect to these key concerns will allow the exploration of appropriate risk management options for industrial uses of substances containing MCCPs.

It is further recommended that the Australian Government Department of Agriculture, Water and the Environment consider including MCCPs in monitoring programs for potential Persistent Organic Pollutants that are not currently listed on the *Stockholm Convention on Persistent Organic Pollutants*. Information from this monitoring activity will inform a further evaluation.

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 $C_{14\text{-}17}$ chloroalkanes according to the third edition of the United Nations' Globally Harmonised System of Classification and Labelling of Chemicals (GHS) is presented below (UNECE, 2009):

Hazard	GHS Classification (Code)	Hazard Statement
Acute Aquatic	Category 1 (H400)	Very toxic to aquatic life
Chronic Aquatic	Category 1 (H410)	Very toxic to aquatic life with long lasting effects

This substance is considered to be a complex mixture (or multi-component substance) for the purposes of classification of aquatic hazards under the GHS. Sufficient measured aquatic toxicity data for MCCP $C_{14\text{-}17,}$ 52% chlorine are available to

classify both the acute and long-term aquatic hazards of the complex mixture. The tested substance is a high purity complex mixture ($C_{14\text{-}17}$, 52% Cl) containing an additional ingredient (stabiliser). This ingredient was not regarded as the relevant ingredient for the purposes of classification of aquatic environmental hazards due to its low concentration (less than 1%) and low aquatic toxicity. The long-term aquatic hazards of this substance were classified taking into consideration that a significant fraction of the chlorinated paraffin congeners in this multi-component substance will be both non-rapidly degradable in the aquatic environment and highly bioaccumulative in aquatic life. The GHS classifications above are consistent with the current GHS classifications under the HCIS (Safe Work Australia, 2018).

References

ANZBP (2017). *Biosolids production in Australia - 2017*. Australian & New Zealand Biosolids Partnership. Accessed May 2019 at https://www.biosolids.com.au.

Brandsma SH, van Mourik L, O'Brien JW, Eaglesham G, Leonards PEG, de Boer J, Gallen C, Mueller J, Gaus C and Bogdal C (2017). Medium-Chain Chlorinated Paraffins (CPs) Dominate in Australian Sewage Sludge. *Environmental Science & Technology,* **51**(6), pp 3364-3372.

Cooley HM, Fisk AT, Wiens SC, Tomy GT, Evans RE and Muir DCG (2001). Examination of the behavior and liver and thyroid histology of juvenile rainbow trout (*Oncorhynchus mykiss*) exposed to high dietary concentrations of C10-, C11-, C12- and C14-polychlorinated n-alkanes. *Aquatic Toxicology,* **54**(1), pp 81-99.

Danish Ministry of the Environment (2014). *Survey of short-chain and medium-chain chlorinated paraffins. Environmental project No. 1614.* Copenhagen, Denmark. Accessed November 2018 at https://www2.mst.dk.

Du X, Yuan B, Zhou Y, Benskin JP, Qiu Y, Yin G and Zhao J (2018). Short-, Medium-, and Long-Chain Chlorinated Paraffins in Wildlife from Paddy Fields in the Yangtze River Delta. *Environmental Science & Technology,* **52**(3), pp 1072-1080.

ECB (2005). *Alkanes, C14-17, chloro (MCCP) Part I - Environment*. European Chemicals Bureau, Ispra, Italy. Accessed June 2019 at https://echa.europa.eu.

ECB (2007). *Alkanes, C14-17, chloro - Addendum to the final report of the risk assessment - Environment part*. European Chemicals Bureau, Ispra, Italy. Accessed June 2019 at https://ec.europa.eu.

ECB (2008). *Risk Assessment of Alkanes, C14-17, Chloro (Medium-Chained Chlorinated Paraffins) Draft of February 2008*. European Chemicals Bureau, Ispra, Italy. Accessed June 2019 at https://echa.europa.eu.

ECHA (2008). *Annex XV Restriction Report*. European Chemicals Agency, Helsinki, Finland. Accessed June 2019 at https://echa.europa.eu.

ECHA (2009). *Medium Chain Chlorinated Paraffins (MCCPs) - Annex XV Transitional Report*. European Chemicals Agency, Helsinki, Finland. Accessed June 2019 at https://echa.europa.eu.

ECHA (2010a). *Conclusion of substance evaluation for transitional dossiers*. European Chemicals Agency, Helsinki, Finland. Accessed June 2019 at https://echa.europa.eu.

ECHA (2010b). *MCCPs PBT/vPvB Evaluation.* European Chemicals Agency, Helsinki, Finland. Accessed June 2019 at https://echa.europa.eu.

ECHA (2012). *CoRAP - Alkanes, C14-17, chloro (MCCP, Medium chained chlorinated paraffins)*. European Chemicals Agency, Helsinki, Finland. Accessed June 2019 at https://echa.europa.eu.

ECHA (2014). *Decision on substance evaluation pursuant to Article 46(1) of Regulation (EC) No 1907/2006*. European Chemicals Agency, Helsinki, Finland. Accessed June 2019 at https://echa.europa.eu.

ECHA (2015). *Decision of the Board of Appeal of the European Chemicals Agency A-004-2014*. European Chemicals Agency, Helsinki, Finland. Accessed June 2019 at https://echa.europa.eu.

ECHA (2018). *Plastic additives initiative - mapping exercise*. European Chemicals Agency, Helsinki, Finland. Accessed April 2019 at https://echa.europa.eu.

ECHA (2019a). *Substance information for Alkanes, C14-17, chloro (CAS RN 85535-85-9).* Helsinki, Finland. Accessed May 2019 at https://echa.europa.eu.

ECHA (2019b). *Registered substances*. European Chemicals Agency, Helsinki, Finland. Accessed April 2019 at https://echa.europa.eu.

ECHA (2019c). *Substance Evaluation Conclusion and Evaluation Report for MCCPs*. Helsinki, Finland. Accessed February 2020 at https://echa.europa.eu.

ECHA (2019d). *RMOA Conclusion for MCCPs*. Helsinki, Finland. Accessed February 2020 at https://echa.europa.eu.

Environment and Climate Change Canada (2008). *Follow-up report on a PSL1 assessment for which data were insufficient to conclude whether the substances were "toxic" to the environment and to the human health Chlorinated Paraffins*. Gatineau, Quebec. Accessed June 2018 at https://www.ec.gc.ca.

Environment and Climate Change Canada (2018a). *Toxic Substances List (Schedule 1): Chlorinated Alkanes*. Environment and Climate Change Canada, Gatineau, Quebec, Canada Accessed June 2019 at https://www.canada.ca.

Environment and Climate Change Canada (2018b). *Chlorinated Paraffins*. Environment and Climate Change Canada. Accessed June 2019 at https://www.ec.gc.ca.

Environment and Climate Change Canada (2019a). *Categorization Results from the Canadian Domestic Substance List*. Provided by OECD. Accessed January 2019 at https://canadachemicals.oecd.org.

Environment and Climate Change Canada (2019b). *Substances Search Engine*. Environment and Climate Change Canada, Gatineau, Quebec, Canada. Accessed June 2019 at https://pollution-waste.canada.ca.

EPHC (2009). *Environmental Risk Assessment Guidance Manual for Industrial Chemicals*. The Department of Environment, Canberra, Australia. Accessed November 2017 at http://www.nepc.gov.au.

Frank U (1993). *Ökotoxizität von Chloroparaffinen. Institut für Wasser- Boden und Lufthygiene, 23 November 1993.* Cited in ECB (2005).

Frank U and Steinhäuser F (1994). Ökotoxizität schwerlöslicher Stoffgemische am Biespiel der Daphnientoxizität von Chlorparaffinen. *Vom Wasser,* **83**, pp 203-211. Cited in ECB (2005).

Gillett RW, Galbally IE, Keywood MD, Powell JC, Stevenson G, Yates A and Borgen AR (2017). Atmospheric short-chain-chlorinated paraffins in Melbourne, Australia – first extensive Southern Hemisphere observations. *Environmental Chemistry,* **14**(2), pp 106-114.

Glüge J, Schinkel L, Hungerbuehler K, Cariou R and Bogdal C (2018). Environmental risks of medium-chain chlorinated paraffins (MCCPs) - A review. *Environmental Science & Technology,* **52**(12), pp 6743-6760.

He C, Brandsma SH, Jiang H, O'Brien JW, van Mourik LM, Banks AP, Wang X, Thai PK and Mueller JF (2019). Chlorinated paraffins in indoor dust from Australia: Levels, congener patterns and preliminary assessment of human exposure. *Science of The Total Environment,* **682**, pp 318-323.

Hilger B, Fromme H, Völkel W and Coelhan M (2011). Effects of Chain Length, Chlorination Degree, and Structure on the Octanol-Water Partition Coefficients of Polychlorinated n-Alkanes. *Environmental Science & Technology,* **45**(7), pp 2842-2849.

Houde M, Muir DCG, Tomy GT, Whittle DM, Teixeira C and Moore S (2008). Bioaccumulation and Trophic Magnification of Short- and Medium-Chain Chlorinated Paraffins in Food Webs from Lake Ontario and Lake Michigan. *Environmental Science & Technology,* **42**(10), pp 3893-3899.

Iozza S, Müller CE, Schmid P, Bogdal C and Oehme M (2008). Historical Profiles of Chlorinated Paraffins and Polychlorinated Biphenyls in a Dated Sediment Core from Lake Thun (Switzerland). *Environmental Science & Technology,* **42**(4), pp 1045-1050.

Ixom (2019a). *Ixom - Water Treatment*. Ixom, Melbourne, Australia. Accessed June 2019 at https://www.ixom.com.

Ixom (2019b). *Ixom - Safety Data Sheet (SDS) Search*. Ixom, Melbourne, Australia. Accessed April 2019 at https://www.ixom.com.

KEMI (2018). *ROHS Annex II Dossier MCCP - Proposal for a restriction of a substance in electrical and electronic equipment under RoHS*. Accessed June 2019 at http://ec.europa.eu.

Kemmlein S, Hermeneit A and Rotard W (2002). Carbon skeleton analysis of chloroparaffins in sediment, mussels and crabs. *Organohalogen Compounds,* **59**, pp 279-282.

Langdon K, Warne M and Kookana R (2010). Aquatic hazard assessment for pharmaceuticals, personal care products, and endocrine-disrupting compounds from biosolids-amended land. *Integrated Environmental Assessment and Management,* **6**(4), pp 663-676.

Levine D (1970). *Fire retardant intumescent paint*. US Secretary of Navy, United States. Accessed June 2019 at https://patents.google.com.

Li T, Gao S, Ben Y, Zhang H, Kang Q and Wan Y (2018). Screening of Chlorinated Paraffins and Unsaturated Analogues in Commercial Mixtures: Confirmation of Their Occurrences in the Atmosphere. *Environmental Science & Technology,* **52**(4), pp 1862-1870.

Ma X, Zhang H, Zhou H, Na G, Wang Z, Chen C, Chen J and Chen J (2014). Occurrence and gas/particle partitioning of short- and medium-chain chlorinated paraffins in the atmosphere of Fildes Peninsula of Antarctica. *Atmospheric Environment,* **90**, pp 10-15.

Miller DR and Wolfe JE (1979). *Traffic paint method and composition*. Prismo Universal Corp, United States. Accessed June 2019 at https://patents.google.com.

Muir D (2010). Environmental levels and fate. In: de Boer J, ed. *Chlorinated Paraffins, Handbook of Environmental Chemistry* Springer-Verlag, Berlin Heide, pp 107-133.

NICNAS (2001). *Chemical Gazette No. C 4, May, 2001 - Australian High Volume Industrial Chemical List. Stage 1, Manufacture.* Sydney, Australia. Accessed August 2018 at http://webarchive.nla.gov.au.

NICNAS (2002). *Australian High Volume Industrial Chemical List*. National Industrial Chemicals Notification and Assessment Scheme, Sydney, Australia. Accessed June 2019 at http://content.webarchive.nla.gov.au.

NICNAS (2004). *Environmental Exposure Assessment of Short Chain Chlorinated Paraffins (SCCPs) in Australia*. National Industrial Chemicals Notification and Assessment Scheme, Sydney, Australia. Accessed June 2019 at https://www.nicnas.gov.au.

NICNAS (2006). *Australian High Volume Industrial Chemical List*. National Industrial Chemicals Notification and Assessment Scheme, Sydney, Australia. Accessed June 2019 at http://www.nicnas.gov.au.

NICNAS (2017). *Inventory Multi-tiered Assessment and Prioritisation (IMAP) Framework*. National Industrial Chemicals Notification and Assessment Scheme, Sydney, Australia. Accessed November 2018 at https://www.nicnas.gov.au.

NICNAS (2018). *Human health tier II assessment for Alkanes, C14-17, chloro-. Australian Government, National Industrial Chemicals Notification and Assessment Scheme*. Accessed October 2018 at https://www.nicnas.gov.au.

Norwegian Climate and Pollution Agency (2013). *Perfluorinated alkylated substances, brominated flame retardants and chlorinated paraffins in the Norwegian Environment - Screening 2013*. NILU, Tromso. Accessed November 2018 at http://www.miljodirektoratet.no.

NPI (2019). *2017/2018 report for IXOM OPERATIONS PTY LTD, Ixom - Chemicals, Chloralkali - Laverton North, VIC*. National Pollutant Inventory, Canberra, Australia. Accessed June 2019 at http://www.npi.gov.au.

OECD (2011a). Series on Emission Scenario Documents, *Emission scenario document on the use of metalworking fluids*. Paris, France. Accessed June 2019 at https://www.oecd-ilibrary.org.

OECD (2011b). Series on Pollutant Release and Transfer Registers, *Resource compendium of PRTR release estimation techniques, Part 4: summary of techniques for releases from products, version 1.0*. Paris, France. Accessed June 2019 at http://www.oecd.org.

OECD (2012a). *SIDS Initial Assessment Profiles agreed in the course of the OECD HPV Chemicals Programme from 1993-2011 - Part 2*. Organisation for Economic Co-operation and Development, Helsinki, Finland. Accessed June 2019 at http://www.oecd.org.

OECD (2012b). *SIDS Initial Assessment Profiles agreed in the course of the OECD HPV Chemicals Programme from 1993-2011 - Part 4*. Organisation for Economic Co-operation and Development, Helsinki, Finland. Accessed June 2019 at http://www.oecd.org.

OECD (2017). *OECD Existing Chemicals Database*. Organisation for Economic Cooperation and Development, Paris, France. Accessed June 2019 at http://webnet.oecd.org.

Omori T, Kimura T and Kodama T (1987). Bacterial cometabolic degradation of chlorinated paraffins. *Applied Microbiology and Biotechnology,* **25**(6), pp 553-557.

Phipps GL, Ankley GT, Benoit DA and Mattson VR (1993). Use of the aquatic oligochaete Lumbriculus variegatus for assessing the toxicity and bioaccumulation of sediment-associated contaminants. *Environmental Toxicology and Chemistry,* **12**(2), pp 269-279.

REACH (2020). *Registration Dossier for Alkanes, C14-17, chloro*. European Chemicals Agency, Helsinki, Finland. Accessed February 2020 at https://echa.europa.eu.

Reth M, Ciric A, Christensen GN, Heimstad ES and Oehme M (2006). Short- and medium-chain chlorinated paraffins in biota from the European Arctic — differences in homologue group patterns. *Science of The Total Environment,* **367**(1), pp 252-260.

Saborido Basconcillo L, Backus SM, McGoldrick DJ, Zaruk D, Sverko E and Muir DCG (2015). Current status of short- and medium chain polychlorinated n-alkanes in top predatory fish across Canada. *Chemosphere,* **127**, pp 93-100.

SA EPA (1997). *South Australian biosolids guidelines for the safe handling, reuse or disposal of biosolids*. Adelaide, Australia. Accessed June 2019 at https://www.lga.sa.gov.au.

Safe Work Australia (2018). *Hazardous Chemical Information System*. Safe Work Australia, Canberra, Australia. Accessed April 2019 at http://hcis.safeworkaustralia.gov.au.

Schinkel L, Lehner S, Knobloch M, Lienemann P, Bogdal C, McNeill K and Heeb NV (2018). Transformation of chlorinated paraffins to olefins during metal work and thermal exposure – Deconvolution of mass spectra and kinetics. *Chemosphere,* **194**, pp 803-811.

Shojania S (1999). The enumeration of isomeric structures for polychlorinated N-alkanes. *Chemosphere,* **38**(9), pp 2125-2141.

Strack H, Cook R and Mann T (2012). *Ullmann's Encyclopedia of Industrial Chemistry - Chlorinated Paraffins*. Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim. Accessed June 2019.

Sutton Tools (2016). *Material Safety Data Sheet - Sutton Venom Cutting Paste*. Accessed April 2019 at https://s3-ap-southeast-2.amazonaws.com.

The Norwegian Ministry of the Environment (2010). *Impact assessment of regulation of medium-chain chlorinated paraffins C14-17 (MCCPs) in consumer products.* Accessed June 2019 at http://www.eftasurv.int.

Thompson R, Williams N and Gillings E (1996). *Chlorinated paraffin (52% chlorinated, C14-17): Acute toxicity to Daphnia magna. Zeneca Confidential Report, BL5871/B.* Cited in ECB (2005).

Thompson R, Smyth D and Gillings E (1997a). *Chlorinated paraffin (52% chlorinated, C14-17): Toxicity to the green alga Selenastrum capricornutum. Zeneca Confidential Report, BL5791/B.* Cited in ECB (2005).

Thompson R, Williams N and Gillings E (1997b). *Chlorinated paraffin (52% chlorinated, C14-17): Chronic toxicity to Daphnia magna. Zeneca Confidential Report, BL5875/B.* Cited in ECB (2005).

Thompson R, Hutchings M and Gillings E (2001a). Medium-chain chlorinated paraffin (52% chlorinated, C14-17): Effects in sediment on emergence of the midge, Chironomus riparius. AstraZeneca Confidential Report BL7093/B. Cited in ECB (2005).

Thompson R, Hutchings M and Gillings E (2001b). *Medium-chain chlorinated paraffin (52% chlorinated, C14-17): Effects in sediment on the survival, growth and reproduction of the freshwater oligochaete, Lumbriculus variegatus. AstraZeneca Confidential Report BL7090/B.* Cited in ECB (2005).

Thompson R, Smyth D and Gillings E (2002). *Medium-chain chlorinated paraffin (52% chlorinated, C14-17): Effects in sediment on the survival, growth and sexual development of the freshwater amphipod, Hyalella azteca. AstraZeneca Confidential Report BL7469/B.* Cited in ECB (2005).

Thompson R (2004). *Medium-chain chlorinated paraffin (C14-17, 52% chlorinated): A comparison of acute toxicity to Daphnia magna using two different carrier solvents and water-accommodated fractions. AstraZeneca Confidential Report, BLS3192/B.* Cited in ECB (2005).

Tomy GT (2010). Analysis of Chlorinated Paraffins in Environmental Matrices: The Ultimate Challenge for the Analytical Chemist. In: de Boer J, ed. *Chlorinated Paraffins, Handbook of Environmental Chemistry* Springer-Verlag, Berlin Heidelberg, pp 83-106.

UNECE (2009). *Globally Harmonised System of Classification and Labelling of Chemicals (GHS), 3rd Revised Edition*. United Nations Economic Commission for Europe, Geneva, Switzerland. Accessed November 2017 at http://www.unece.org

UNEP (1987). *The Montreal Protocol on Substances that Deplete the Ozone Layer*. United Nations Environment Programme, Ozone Secretariat, Nairobi, Kenya. Accessed June 2019 at http://ozone.unep.org.

UNEP (2001). *The Stockholm Convention on Persistent Organic Pollutants*. United Nations Environment Programme Secretariat of the Stockholm Convention, Châtelaine, Switzerland. Accessed 10 November 2017 at http://www.pops.int.

UNEP (2011). *Case study on toxicological interactions of chlorinated paraffins. UNEP/POPS/POPRC.7/INF/15*. Geneva. Accessed October 2018 at http://chm.pops.int.

UNEP (2015). *Risk profile on short-chained chlorinated paraffins. UNEP/POPS/POPRC.11/10/Add.2.* United Nations Environment Programme, Secretariat of the Stockholm Convention, Châtelaine, Switzerland. Accessed June 2019 at http://chm.pops.int.

UNEP (2016a). *Additional information related to the draft risk management evaluation on short-chain chlorinated paraffins. UNEP/POPS/POPRC.12/INF/7.* Châtelaine, Switzerland. Accessed June 2019 at http://chm.pops.int.

UNEP (2016b). *Report of the Persistent Organic Pollutants Review Committee on the work of its twelfth meeting. Addendum. Risk management evaluation on short-chain chlorinated paraffins. UNEP/POPS/POPRC.12/11/Add.3*. Châtelaine, Switzerland. Accessed June 2019 at http://chm.pops.int.

UNEP & FAO (1998). *The Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade*. United Nations Environment Programme and Food and Agriculture Organization of the United Nations, Châtelaine, Switzerland. Accessed March 2019 at http://www.pic.int.

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

US EPA (2009). *Short-chain chlorinated paraffins (SCCPs) and other chlorinated paraffins action plan*. United States Environmental Protection Agency, Washington DC, USA. Accessed 28 August 2018 at https://www.epa.gov.

US EPA (2015a). *TSCA New Chemicals Review Program Standard review risk assessment on medium-chain chlorinated paraffins (PMN P-12-0282, P-12-0283) and long-chain chlorinated paraffins (PMN P-12-0284)*. Accessed 14 June 2018 at https://www.epa.gov.

US EPA (2015b). *TSCA New Chemicals Review Program Standard review risk assessment on medium-chain chlorinated paraffins (PMN P-12-0453) and long-chain chlorinated paraffins (PMN P-12-0433)*. Accessed June 2019 at https://www.epa.gov.

US EPA (2017). *TSCA Section 5 Order for Alkanes, C14-17, chloro, 85535-85-9. Consent order for PMN P-12-0433,*. Accessed June 2019 at https://chemview.epa.gov.

US EPA (2018a). *Significant New Use Rules on Certain Chemical Substances*. United States Environment Protection Agency, Washington, DC, USA. Accessed April 2019 at https://www.federalregister.gov.

US EPA (2018b). *Reviewing New Chemicals under the Toxic Substances Control Act (TSCA). Chlorinated Paraffin Premanufacture Notifications.* Accessed June 2018 at https://www.epa.gov.

van Mourik LM, Gaus C, Leonards PEG and de Boer J (2016). Chlorinated paraffins in the environment: A review on their production, fate, levels and trends between 2010 and 2015. *Chemosphere,* **155**, pp 415-428.

Wong F, Suzuki G, Michinaka C, Yuan B, Takigami H and de Wit CA (2017). Dioxin-like activities, halogenated flame retardants, organophosphate esters and chlorinated paraffins in dust from Australia, the United Kingdom, Canada, Sweden and China. *Chemosphere,* **168**, pp 1248-1256.

Yuan B, Brüchert V, Sobek A and de Wit CA (2017). Temporal Trends of C8–C36 Chlorinated Paraffins in Swedish Coastal Sediment Cores over the Past 80 Years. *Environmental Science & Technology,* **51**(24), pp 14199-14208.

Yuan B, Vorkamp K, Roos AM, Faxneld S, Sonne C, Garbus SE, Lind Y, Eulaers I, Hellström P, Dietz R, Persson S, Bossi R and de Wit CA (2019). Accumulation of Short-, Medium-, and Long-Chain Chlorinated Paraffins in Marine and Terrestrial Animals from Scandinavia. *Environmental Science & Technology,* **53**(7), pp 3526-3537.

Zeng L, Lam JCW, Chen H, Du B, Leung KMY and Lam PKS (2017). Tracking Dietary Sources of Short- and Medium-Chain Chlorinated Paraffins in Marine Mammals through a Subtropical Marine Food Web. *Environmental Science & Technology,* **51**(17), pp 9543-9552.

Zitko V (1980). Chlorinated Paraffins. In: Hutzinger O, ed. *The Handbook of Environmental Chemistry*. Springer-Verlag, Berlin Heidelberg, pp 149-179.