Support document for UK proposal to list "Chlorinated paraffins with carbon chain lengths in the range C_{14-17} and chlorination levels at or exceeding 45% chlorine by weight" in Annex A, B or C to the Stockholm Convention on Persistent Organic Pollutants

1. Introduction

1. Chlorinated paraffins (CPs) are manufactured substances consisting of predominantly linear chloroalkanes, with different degrees of chlorination and chain length distributions depending on the application and feedstock. This proposal is for any CP product that has constituents with 14 to 17 carbon atoms (C_{14-17}) and a chlorination level at or exceeding 45% chlorine by weight (Cl wt.). These congeners are the principal constituents of substances called "medium-chain chlorinated paraffins" (MCCPs) in Europe, North America and Australia, and major constituents of several products manufactured in Asia (e.g. CP-52). Due to the possible confusion regarding different product names, the proposal for listing is based on specific chain lengths and degrees of chlorination. Nevertheless, most of the available hazard and monitoring information is available from assessments on the substance called MCCPs, and so the term "MCCPs" is used in these instances.

2. Regulatory status

2. "MCCPs" (alkanes, C_{14-17}, chloro; CAS no. 85535-85-9) was assessed in Europe under the Existing Substances Regulation (EC) No. 793/93 (EC, 2005; EC, 2007; HSE 2008), and via a transitional Annex XV dossier under the Registration, Evaluation and Authorisation of Chemicals (REACH) Regulation (Environment Agency, 2010). Subsequently "MCCPs" underwent Substance Evaluation under REACH, and the published report prepared by the UK concludes that it meets the REACH Annex XIII criteria for Persistent, Bioaccumulative and Toxic (PBT) and very Persistent, very Bioaccumulative (vPvB) properties (Environment Agency, 2019). A proposal to identify "MCCPs" as a Substance of Very High Concern due to its PBT/vPvB properties has been prepared by the European Chemicals Agency (ECHA), and was available for public comment until 23rd April 2021 (ECHA, 2021a). This proposal for Stockholm Convention listing is principally based on the REACH Substance Evaluation report, which focused on the assessment of environmental endpoints. A further analysis prepared by Germany indicates concern for several uncontrolled risks for human health from MCCPs, and uncertainty for specific toxicological endpoints (BAUA, 2020; Zellmer *et al*., 2020).

3. The Australian Department of Health published a hazard assessment of "MCCPs" in June 2020 (NICNAS, 2020). The review concluded that "MCCPs" meets the domestic PBT criteria, and that some congener groups may meet the Annex D screening criteria for Persistent Organic Pollutants under the Stockholm Convention.

4. Environment and Climate Change Canada reviewed the CPs group in 2008 (Environment Canada, 2008). The review concluded that “MCCPs” is "toxic"[1] as defined in paragraphs 64 (a) and (c) of the Canadian Environmental Protection Act, 1999.

3. Chemical identity

3.1. CAS number, chain length and chlorination

5. Key information for CPs with $C_{14\text{-}17}$ chain lengths is provided in Table 1, based on Environment Agency (2019). A non-exhaustive list of relevant CAS numbers is provided in Appendix 3, together with further information (such as additives). Around forty CAS numbers have been used to describe the CP family at various times. Some of these clearly cover CPs in the $C_{14\text{-}17}$ range, and it is possible that some of the remainder may be used for products containing CPs in this range too.

Table 1: Substance identity

IUPAC name	Alkanes, $C_{14\text{-}17}$, chloro
CAS number	85535-85-9
EC number	287-477-0
Molecular formula	$C_xH_{(2x - y+2)}Cl_y$, where x = 14 to 17 and y = ≥5 to 17
Molecular weight range	370 - 826 g/mole (approximately)
Synonyms	Medium-chain chlorinated paraffins (MCCPs); Chlorinated paraffins, $C_{14\text{-}17}$ (used in Annex VI of the CLP Regulation)

6. The predominant chain length of “MCCPs” is in the range $C_{14\text{-}17}$, reflecting the hydrocarbon feedstocks used in its manufacture within Europe, North America and Australia. Information presented in Environment Agency (2019) indicates that commercially supplied “MCCP” products are likely to include a significant proportion of the chlorinated C_{14} carbon chain lengths. They also contain some constituents outside of the $C_{14\text{-}17}$ range in small amounts.

7. CPs produced in Asian countries such as India and China are differentiated based on their chlorine content (or viscosity) rather than by the carbon chain lengths of their constituent congeners. An example is the product CP-52, which accounts for 80% of the total commercial CP production in China (Wei *et al*., 2016). This contains $C_{9\text{-}30}$ chain lengths with a significant fraction in the range $C_{14\text{-}17}$ (Castro *et*

[1] The substance is entering, or may enter, the environment in quantities or concentrations or under conditions that: have or may have an immediate or long-term harmful effect on the environment or its biological diversity, or constitute or may constitute a danger in Canada to human life or health.

al., 2018). For both "MCCPs" and products such as CP-52, chain lengths below C_{14} are structurally analogous to the range described as short-chain chlorinated paraffins (SCCPs – see paragraph 12).

8. The chlorine content of commercial products (e.g. "MCCPs" and CP-52) varies according to the applications they are used for, but is generally within the range 40% to 63% by weight; the majority of products have a chlorine content between 45% and 52% by weight. The chlorination process is random, and so all of these products contain many thousands of constituents[2].

9. Table 2 indicates the structural formulae of possible constituents of the different product types (adapted from information originally presented in EC (2000) and EC (2005)). The "blocks" in the table still contain large numbers of individual isomers. The main constituents in the majority of product types have between five and seven chlorine atoms per molecule. Nevertheless, it should be noted that percentage chlorine content only represents an average level of chlorination, and so a wider range of constituents may be present in any particular product.

10. Available regulatory laboratory testing for "MCCPs" has been undertaken using substances with a specified chlorine content, such as 50% Cl wt. The assessment approach for this proposal is aligned with these data. The exact constituents of "MCCPs" will always be variable and a block approach as shown in Table 2 is a recognised way of addressing this uncertainty. An alternative approach is to assess the substance based on the number of chlorine atoms per chain length. For laboratory studies this requires an assumption about which congeners were present in the test, and at what concentration, as in many cases congener-specific analysis is not available. Applying such an approach then requires an assumption of equality, rather than trends, across the different congeners to interpret each test for a specific property. Where congener-specific analysis is available, it also requires verification of the accuracy of the analysis to quantify the individual congener concentrations (including their representativeness where extrapolation from specific constituents to the whole congener group is made).

Table 2: Theoretical chlorine content of constituents for $C_{14\text{-}17}$ chain lengths

Chlorine content,% w/w	**Carbon chain length**			
	C_{14}	**C_{15}**	**C_{16}**	**C_{17}**
<40	$C_{14}H_{29}Cl$ to $C_{14}H_{27}Cl_3$	$C_{15}H_{31}Cl$ to $C_{15}H_{29}Cl_3$	$C_{16}H_{33}Cl$ to $C_{16}H_{30}Cl_4$	$C_{17}H_{35}Cl$ to $C_{17}H_{32}Cl_4$
40 - 45	$C_{14}H_{26}Cl_4$	$C_{15}H_{28}Cl_4$	$C_{16}H_{29}Cl_5$	$C_{17}H_{31}Cl_5$
45 - 50	**$C_{14}H_{25}Cl_5$**	**$C_{15}H_{27}Cl_5$**	**$C_{16}H_{28}Cl_6$**	**$C_{17}H_{30}Cl_6$**

[2] Tomy *et al*. (1997) includes a formula for the calculation of the number of isomers.

Chlorine content,% w/w	Carbon chain length			
	C_{14}	**C_{15}**	**C_{16}**	**C_{17}**
50 - 55	**$C_{14}H_{24}Cl_6$**	**$C_{15}H_{26}Cl_6$ & $C_{15}H_{25}Cl_7$**	**$C_{16}H_{27}Cl_7$**	**$C_{17}H_{29}Cl_7$**
55 - 65	**$C_{14}H_{23}Cl_7$ to $C_{14}H_{21}Cl_9$**	**$C_{15}H_{24}Cl_8$ to $C_{15}H_{22}Cl_{10}$**	**$C_{16}H_{26}Cl_8$ to $C_{16}H_{23}Cl_{11}$**	**$C_{17}H_{28}Cl_8$ to $C_{17}H_{25}Cl_{11}$**
>65	**$C_{14}H_{20}Cl_{10}$ and higher no. of Cl atoms**	**$C_{15}H_{21}Cl_{11}$ and higher no. of Cl atoms**	**$C_{16}H_{22}Cl_{12}$ and higher no. of Cl atoms**	**$C_{17}H_{24}Cl_{12}$ and higher no. of Cl atoms**

(**bold text** indicates those blocks within scope of the proposal)

3.2. Structural formula

11. Two example structures (hydrogen atoms removed for simplicity) of CPs with C_{14} and C_{17} chain lengths are shown in Figure 1

$C_{14}H_{24}Cl_6$ $C_{17}H_{29}Cl_7$

Figure 1: Structures of two representative constituents of CPs with C_{14} and C_{17} chain lengths

3.3. Analogues

12. SCCPs (containing $C_{10\text{-}13}$ carbon chain lengths) and long-chain chlorinated paraffins (LCCPs, containing $C_{18\text{-}30}$ carbon chain lengths) are structural analogues registered under EU REACH. SCCPs was listed as a Persistent Organic Pollutant (POP) in 2017. Commercial "MCCPs" contains $C_{10\text{-}13}$ constituents that may be analogous to SCCPs, at levels typically below 1% by weight (often much lower), although the identity and actual concentration of the individual constituents is not known.

13. HSE (2008) indicated that LCCPs based on a $C_{18\text{-}20}$ carbon chain length may contain up to 20% C_{17} CPs. An earlier report assessing LCCPs (Environment Agency, 2009) is currently being updated by the UK following the substance evaluation of "MCCPs" in the EU (Environment Agency, 2021 in prep.). As pointed out in paragraph 7, some Asian products (e.g. CP-52) contain LCCP chain lengths

together with MCCP and SCCP chain lengths (and $C_{<10}$ constituents) in a single product.

14. Further details of the analogues are provided in Appendix 3.

4. Physico-chemical properties

15. Key data relevant to this proposal are summarised in Table 3. The complexity and variability of the commercial substance means that many of the values represent averages. For example, the log K_{OW} will have a range covering several orders of magnitude, reflecting the wide variety of congeners present. This value may change for products with different degrees of chlorination. A standardised set of measurements covering all major constituent blocks at differing degrees of chlorination is not available, although some attempts have been made to look for patterns using predictive software (e.g. Glüge *et al*., 2013).

Table 3: Physicochemical properties for CPs with $C_{14\text{-}17}$ chain lengths

Property	**Value**	**Source of information/remarks**
Physical state at 20 °C and 101.3 kPa	Liquid	EC, 2005
Melting / freezing point	The pour point varies between -50 °C and +25 °C, depending on degree of chlorination	EC, 2005
Boiling point	Decomposition occurs at around 200 °C before boiling	EC, 2005
Vapour pressure	1.3×10^{-4} to 2.7×10^{-4} Pa at 20 °C for $C_{14\text{-}17}$ chlorinated n-alkane, 52% Cl wt. 1.07×10^{-3} Pa at 45 °C, 6×10^{-3} Pa at 60 °C and 0.051 Pa at 80 °C for $C_{14\text{-}17}$ chlorinated n-alkane, 52% Cl wt.; 2.27×10^{-3} Pa at 40 °C and 0.16 Pa at 80 °C for $C_{14\text{-}17}$ chlorinated n-alkane, 45% Cl wt.	Campbell and McConnell, 1980 BUA, 1992 as cited in EC, 2005
Water solubility	0.0061 mg/L at 20 °C for C_{14} chlorinated n-alkane, 50% Cl wt.	Unpublished, 2019a; non-GLP[1] OECD Test Guideline (TG) 105. Analytical method: APCI-ToF-HRMS. Study considered to be reliable without restriction.

Property	Value	Source of information/remarks
	0.005 - 0.027 mg/L at 20 °C for C_{15} chlorinated n-alkane, 51% Cl wt.	Madeley *et al*., 1983a; non-standard method. Analytical method: thin-layer chromatography and radioactivity measurements. Key study used in EC (2005) and considered to be a realistic upper limit for this substance.
	0.01 mg/L in freshwater and 0.004 mg/L in seawater at 16-20 °C for C_{16} chlorinated n-alkane, 52% Cl wt.	Campbell and McConnell, 1980; method unknown. Analytical method: radioactivity measurements
Partition coefficient n-octanol/water (log K_{OW})	6.58 ± 0.09 for C_{14} chlorinated n-alkane, 50% Cl wt.	Unpublished, 2019b; non-GLP OECD TG 123 (slow stir). Analytical method: APCI-ToF-HRMS. Very little variability in K_{OW} was observed between differently chlorinated congener groups. Study considered to be reliable without restriction.
	7.2 (4.7-8.3) for C_{16} chlorinated n-alkane, 35% Cl wt.	Fisk *et al*., 1998a; key study used in EC (2005). Analytical method: high performance liquid chromatography (HPLC). Study considered to provide indicative information only.
	5.52 to 8.21 for $C_{14\text{-}17}$ chlorinated n-alkane, 45% Cl wt.; 5.47 to 8.01 for $C_{14\text{-}17}$ chlorinated n-alkane, 52% Cl wt.	Renberg *et al*. (1980); non-GLP non-guideline study. Analytical method: reversed-phase high performance thin layer chromatography (RP-HPTLC). Study considered to provide indicative information only.

Note: GLP – Good Laboratory Practice.

5. Information in relation to the Annex D screening criteria

5.1. Chemical analytical challenges

16. The highly complex nature of CPs means that there are considerable analytical challenges associated with their detection and quantification. Only limited information is available on the actual carbon chain length distribution and chlorine contents of the CPs detected in environmental samples, although advances in analytical methodologies have meant that more detail has been possible in some of the more recent studies. The current recommended analytical method is APCI-QToF-HRMS[3]. In an inter-laboratory comparison by van Mourik *et al*. (2018), the most commonly used analytical technique for SCCPs analysis – GC-ECNI-LRMS[4] – showed the largest variation, and the same is likely to be true for longer chains. High Resolution Mass Spectrometry (HRMS) was recommended to be used in future. The degree of chlorination can also be important, especially if the substance in a sample differs from the analytical standards used. Based on work of Brandsma *et al*. (2017), Bogdal *et al.* (2015) and Yuan *et al.* (2017), there remains uncertainty with the identification and quantification of "MCCPs" congeners with less than 5 chlorine atoms. Furthermore some commonly used low resolution mass spectrometry methods may be subject to interferences from both the matrix and other contaminants (such as chlordanes, polychlorobiphenyls and toxaphenes) unless highly efficient sample clean-up procedures are used. A large proportion of measured values reported in the academic literature may therefore be unreliable. In general, detections of "MCCPs" in biota and the environment are considered to be qualitative indicators only in the following discussion.

5.2. Persistence

5.2.1. Abiotic data

17. Data for photodegradation in air are discussed in the Long Range Transport section.

18. Koh and Thiemann (2001) investigated the degradation of CPs in water through photochemical dechlorination. The reported half-life in water was 9.6 h for a $C_{17\text{-}24}$ n-alkane, 35% Cl wt. and 12.8 h for a $C_{12\text{-}18}$ n-alkane, 52% Cl wt. However, the relevance of photodegradation is likely to be low in most natural waters due to depth, turbidity, quenching agents, etc. Due to their structure, CPs are not expected to hydrolyse significantly.

19. In summary, photodegradation may occur in water, but the relevance to overall environmental persistence is limited. Hydrolysis is not a significant degradation pathway.

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[3] APCI-QToF-HRMS: Atmospheric-Pressure Chemical Ionization Quantitative Time of Flight High Resolution Mass Spectrometry

[4] GC-ECNI-LRMS: Gas Chromatography Electron Capture Negative Ionisation Low Resolution Mass Spectrometry

5.2.2. Biotic data

5.2.2.1. Biotic screening data

20. Environment Agency (2019) details a number of biodegradation screening studies investigating the influence of chain length and chlorination level on biodegradation potential of CPs with C_{14-17} chain lengths. These were mostly[5] based on the OECD TG 301 using modified conditions by including a surfactant (alkylphenol polyalkoxylate) to increase bioavailability, and in some cases an extended time period for the test.

21. Under the conditions of these studies, C_{14} chlorinated n-alkanes with a chlorine content of 41.3% and 45.5% were readily biodegradable within 28 days. C_{14} chlorinated n-alkane, 50% Cl wt. failed to meet the 60% pass threshold within 28 days but did meet it after 56 days.

22. Both a 55% and 60% Cl wt. C_{14} chlorinated n-alkane failed to meet the pass threshold of 60% degradation even after 60 days. A C_{15} chlorinated n-alkane, 51% Cl wt. also failed to meet the pass threshold after 60 days.

23. C_{14-17} chlorinated n-alkane, 45.5% Cl wt. achieved 51% degradation after 28 days (and so was not readily biodegradable), although a test using an extended timescale was not available. C_{14-17} chlorinated n-alkane, 51.7% Cl wt. was not readily biodegradable in 28 days (achieving 27% degradation) and although it was extensively degraded over an extended period (57% degradation after 60 days) it still failed to meet the pass threshold. C_{14-17} chlorinated n-alkane, 63.2% Cl wt. only achieved 10% degradation under the same conditions.

24. In summary, the studies indicate that substances with a lower level of chlorination can be extensively degraded by micro-organisms under conditions of enhanced bioavailability. The trend in the data shows that degradability reduces as the number of chlorine atoms per molecule increases. Longer chain lengths are expected to be less water soluble and more adsorptive than the C_{14} and C_{15} substances, but there are no degradation data for specific C_{16} or C_{17} substances, so the actual influence of chain length cannot be confirmed.

25. It should be noted that it is not possible to extrapolate information from these screening tests to an environmental half-life.

5.2.2.2. Environmental simulation data

26. A measured environmental half-life in water, typically obtained using OECD TG 309 (aerobic mineralisation in surface water – simulation biodegradation test), is not available for CPs with C_{14-17} chain lengths. Given their low water solubility, such a study would be challenging to perform.

[5] A number of studies used an inoculum that was not considered to be appropriate for the REACH Annex XIII assessment, and similarly not considered appropriate for the Annex D screening criteria. Three tests were also performed using OECD TG 302A (Inherent Biodegradability: Modified SCAS Test), but the high inoculum concentrations used in these studies mean that the results are not relevant for persistence assessment. In both cases the data are not summarised in this proposal.

27. An OECD TG 308 (aerobic and anaerobic transformation in aquatic sediment systems) study has been conducted using non-radiolabelled C_{14} chlorinated n-alkane, 50% Cl wt., in accordance with GLP (Unpublished, 2019c and 2019d). This is described in detail in Environment Agency (2019). The test was conducted at 12 °C in the dark under aerobic conditions. Two types of natural sediment and their associated overlying waters were used: a high organic carbon sediment (4.65%) with a fine texture (Brandywine Creek) and a low organic carbon content (0.55%) with a coarse texture (Choptank River). Test vessels were acclimated for 12 days prior to dosing. The test substance was dissolved in a solvent and mixed with fine quartz sand before the solvent was removed via rotary evaporation. The treated sand was then applied to each test vessel to give a nominal test substance concentration of 5 µg/g dry weight (dw) in sediment. Test sub-groups consisted of treated live vessels, treated inactivated vessels (inactivated by freezing immediately after dosing), and untreated (blank) control vessels. Additional vessels were set up for characterization measurements (without addition of test substance), and were maintained under the same test conditions as vessels used to monitor transformation. Parameter measurements consisted of pH, total organic carbon, dissolved oxygen, redox, and microbial biomass measurements for both the water and sediment made at the start of acclimation, and day 0, 60 and 120. Test vessels were sacrificed on days 0, 15, 30, 45, 60, 91 and 120 (the test guideline specifies that the test should not be run for longer than 100 days). Chemical analysis was performed using APCI-ToF-HRMS.

28. Apart from a single measurement at 91 days, the mean measured concentrations from all sampling intervals did not deviate by greater than 8% (calculated relative standard deviation; RSD) of the applied nominal concentration. Congener-specific analyses[6] for the extracted samples showed no significant variation between these extracts, the extracted spiked sand and the original test substance. Overall the chemical analysis showed no observable biotransformation in two different sediments, and so the sediment half-life was >120 days at 12 °C. The study is assessed to be reliable without restriction.

29. No data are available on the biodegradation of CPs with $C_{14\text{-}17}$ chain lengths in soil, for example in accordance with OECD TG 307 (aerobic and anaerobic transformation in soil).

30. In summary, while a modified screening biodegradation test using C_{14} chlorinated n-alkane, 50% Cl wt. indicated extensive biodegradation after 56 days, no degradation occurred in the OECD TG 308 study. Since the simulation test is more environmentally relevant, it is given the greatest weight in the assessment of persistence. The negligible degradation rate in aerobic sediment may reflect a reduction in bioavailability caused by adsorption. Longer chain lengths with similar or higher degrees of chlorination appear to be less degradable than C_{14} chlorinated n-alkane, 50% Cl wt. based on screening biodegradation test data. However, C_{14}

[6] As per paragraph 16, there maybe uncertainty regarding the analysis of lower chlorinated congeners (<5 chlorine atoms).

chlorinated n-alkanes with ≤45% chlorination are readily biodegradable, so should not be treated as persistent. It is not known whether this finding would apply to longer chain lengths with a similarly low degree of chlorination.

5.2.2.3. Environmental compartment monitoring

Environmental monitoring data are summarised in Appendix 5. CPs have been detected in sediment cores taken from several locations around the world, and this section focuses on these studies as they are relevant to the laboratory data summarised in Section 5.2.2.2.

31. Iozza *et al.* (2008) took a 1.1 m sediment core from Lake Thun, Switzerland in May 2005. The lake is located in a rural, densely populated alpine catchment area without any known point sources (e.g. metal or polymer industries). The average sedimentation rate was determined to be 0.45 cm/year. The level of “MCCPs” in the sediment core showed an increasing trend from 1965 onwards reaching a level of 26 µg/kg dw in the surface layer (i.e. 2004). Concentrations between 15 and 20 µg/kg dw were evident in the samples dated to the 1980s. The C_{14} carbon chain length was the most abundant constituent present (accounting for 41 to 64% of the total “MCCPs”). Chlorine content was higher from the cores dated between 1994 and 2004 (generally between 53.3% and 56.6% by weight).

32. Chen *et al.* (2011) took a sediment core from the Dongjiang River within Dongguan in the Pearl River Delta area of south China. The sediment core was collected to a depth of approximately 68 cm and was thought to contain about 15 years of deposition as it was known that the sedimentation rate in the area was 4 to 6 cm/year. The concentrations of “MCCPs” were higher in the upper layers of the core than in the deeper layers; 1 400 to 3 800 µg/kg dw between 0 and 32 cm depth compared with 1 100 to 1 400 µg/kg dw between 36 and 68 cm depth. The increasing concentrations in the upper layers were thought to be a result of increasing use of “MCCPs” in the area. The “MCCP” concentrations in the lower layers were relatively constant. It was noted that there was a higher relative abundance of C_{16} and C_{17} substances in the upper layers (from 0 cm to around 44 cm depth) than in the lower layers, with the relative proportion of C_{14} substances being higher in the lower layers than the upper layers. It was suggested that this may reflect changes in the composition of “MCCPs” used in the area over time. Similar to Iozza *et al.* (2008), higher levels of chlorination were seen for more recent cores.

33. “MCCPs” were detected at concentrations ranging from 750 to 1 200 µg/kg dw in sediment cores from Lake St. Francis, downstream of Cornwall, Ontario, Canada (Muir *et al.*, 2002). Based on the data, Environment Canada (2008) estimated the half-life of “MCCPs” in sediments to be longer than 1 year.

34. Sediment cores were taken by Yuan *et al.* (2017) at three different locations in Sweden (downstream of a wastewater treatment plant, near to a wood industrial area, and to a steel factory). Using APCI-QToFMS analysis, the authors detected “MCCPs” at concentrations of < 6.5 to 93 µg/kg dw. This included detection in sediment from cores dated as 1954 and 1960. Furthermore, temporal trends could

be seen indicating a decrease in SCCPs reflecting their restriction, and a concurrent increase in “MCCPs”.

35. Sediment cores were taken from 2 urbanised coastal locations: Hong Kong waters (1 core, taken in 2004) and Tokyo Bay (2 cores taken in 2012) by Zeng *et al.* (2017a). These were analysed for SCCPs and “MCCPs” using GC-ECNI-LRMS. “MCCPs” were detected in horizons that were estimated to have been deposited in the late 1950s in both locations. Surface concentrations were 20.3 µg/kg dw in Hong Kong waters, and 7.9 and 29.3 µg/kg dw in the Tokyo Bay (2-4 cm) cores, although these represent different sampling times so are not comparable. The maximum historic concentration in the cores were from the late 1980s: 180 µg/kg dw in the Tokyo Bay cores, and 7.3 µg/kg dw in the Hong Kong waters core. Declines in both SCCPs and “MCCPs” concentrations were noted in Tokyo Bay from the 1990s to more recent periods, which were suggested by the authors to reflect declining manufacture and use due to regulatory controls introduced in the early 2000s. However, in both cores the concentration in the uppermost core slice are within an order of magnitude of the levels in core slices from the previous 8 years. Recent trends in the Hong Kong waters core cannot be discerned due to the older core sampling date.

36. Zhang *et al.* (2019) took sediment cores from the deepest location of 9 lakes in China, including 2 located in areas remote from industry (Lake Qinhgai and Lake Bosten, situated in the Tibetan Plateau and Mengxin lake regions of north-western China). The majority of cores were taken in 2006 and cover a period from about 1930. Complementary surface sediment samples were taken in 2018 and 2019, together with four shallower sediment cores taken between 2011 and 2019 from the non-remote lakes. All cores were analysed for CPs using UPLC-QToFMS[7] (analysis appears to have been performed in 2019). Concentrations were low or below 5.0 µg/kg dw (the limit of detection) until the 1970s, after which the lowest surface “MCCPs” concentrations (35 to 269 µg/kg dw) were observed in the remote lakes, with higher surface “MCCPs” concentrations in lakes near to larger cities and manufacturing industries (643 to 3 390 µg/kg dw). For the more contemporary cores from non-remote lakes, “MCCPs” concentrations in the top slice are similar to those in the slices for the period back to the early 1990s. The homologue profile of “MCCPs” was noted to be similar in nearly all lakes, with the C_{14} chain length and the Cl_7 and Cl_8 chlorination levels dominant. The authors indicate the distribution observed is similar to CP-42, a commercial Chinese product. “MCCPs” as a proportion of overall detected CPs in the cores was noted to be increasing, with SCCPs decreasing.

37. In summary, measurable levels of “MCCPs” are present in deeper (older) sediment layers that are of the same order of magnitude as levels in surface (recent) layers. This provides indirect evidence that the substance may be persistent in sediments

[7] Ultra-Performance Liquid Chromatography to Quadrupole Time-Of-Flight Mass Spectrometry

over many years. It is acknowledged that degradation conditions (e.g. redox potential) will vary with depth, and levels will also depend on the environmental emission at the time of deposition.

5.2.3. Persistence synthesis

38. The key data are the absence of transformation of a C_{14} chlorinated n-alkane, 50% Cl wt. substance after 120 days at 12 °C in a reliable OECD TG 308 study performed to GLP. The absence of degradation at 120 days in the study suggests that it is very unlikely that significant degradation would subsequently occur between 120 and 180 days. This hypothesis is supported by the sediment core monitoring data where levels of “MCCPs” are at similar orders of magnitude in horizons representing deposition from 8 or more years ago older and surface sections of the same core.

39. All of the substances that were tested and shown to be less degradable than C_{14} chlorinated n-alkane, 50% Cl wt. in the modified and enhanced ready tests are likely to have similar or longer sediment half-lives to the C_{14} (50% Cl wt.) congener block. Given the predicted and observed trends in physico-chemical properties, it is likely that $C_{15\text{-}17}$ constituents with similar or higher chlorine contents to C_{14} chlorinated n-alkane, 50% Cl wt. will be equally or more adsorptive to sediment. They are therefore likely to be equally or more persistent in sediment (i.e. the sediment half-lives will exceed 180 days).

40. C_{14} chlorinated n-alkanes with a low chlorine content (≤45% Cl wt.) are readily biodegradable, although it is noted that a $C_{14\text{-}17}$ chlorinated n-alkane, 45.5% Cl wt. was not readily biodegradable despite extensive mineralisation. It is possible that adsorption could cause these substances to have longer sediment half-lives than expected, but no robust data are available to allow a conclusion to be drawn. Given that the test results for these specific C_{14} constituents would meet the OECD definition of “readily biodegradable”, chain lengths below 45% Cl wt. are excluded from this proposal. Whilst it is possible that more highly chlorinated (persistent) constituents might be present in the <45% Cl wt. fraction used in the screening studies, the high level of mineralisation attained in these specific screening studies suggests that the concentration of any potentially persistent constituents present is likely to be extremely low, and therefore not considered relevant.

41. Overall, the Annex D criteria for persistence 1b(i) are considered to be met as the half-life for sediment is assessed to exceed 180 days for C_{14} constituents, and by analogy $C_{15\text{-}17}$ constituents, with chlorination levels ≥45% Cl wt. $C_{14\text{-}17}$ constituents with lower chlorination levels are not considered to be persistent based on the currently available information.

5.3. Bioaccumulation

5.3.1. Screening information

42. As shown in Table 3, the constituents of CPs with $C_{14\text{-}17}$ chain lengths have a range of log K_{OW} values, but all measured values exceed 5. C_{14} chlorinated n-alkane,

50% Cl wt. has a reliable measured log K_{OW} of 6.6. Given the expected increase in hydrophobicity with increasing chain length and chlorination level, the majority of constituents within CPs with $C_{14\text{-}17}$ chain lengths are likely to have a log K_{OW} around or above this value.

5.3.2. Aquatic fish bioaccumulation studies

43. A reliable fish bioconcentration study with Rainbow Trout (*Oncorhynchus mykiss*) was conducted according to OECD TG 305 and GLP using a ^{14}C radio-labelled C_{14} chlorinated n-alkane, 45% Cl wt. product (Unpublished, 2010a and 2010b). This is detailed in Environment Agency (2010). The test used a single aquatic exposure concentration during uptake. This was nominally 0.5 µg/L, which was well below the water solubility limit. The mean measured concentration was 0.34 µg/L. Dimethyl formamide was used as a solvent with a concentration in the vessel of 0.004 mL/L. The fish were exposed to the substance for 35 days followed by a 42-day depuration period, under flow-through conditions. Measurements of fish lipid and growth were made during the study, and fish growth was found to be significant. In follow-up analytical work, it was determined that around 79% of the measured radioactivity was likely to be parent substance (Unpublished, 2010b). The remaining 21% was associated with non-polar non-extractable metabolites. These were not further identified, and so it is not known whether these are toxic or accumulative. For the purpose of this proposal, the fish bioconcentration factor (BCF) is calculated using a conservative assumption that all measured radioactivity is relevant. The growth-corrected and lipid-normalised kinetic BCF is therefore 14 600 L/kg. If the apparent metabolites are ignored, the value would be around 11 530 L/kg for parent substance alone. The study is assessed to be 'reliable without restriction', although the reported lipid-normalised "steady state" BCF (BCFss) of 3 230 L/kg should be treated with considerable caution as the fish were growing and so a true steady state had not been reached.

44. A reliable fish dietary bioaccumulation test with Rainbow Trout (*O. mykiss*) was conducted according to OECD TG 305 and GLP using a C_{14} chlorinated n-alkane, 50% Cl wt. substance in a flow-through system (Unpublished, 2019e and 2019f). A dosed treatment containing the test substance at a nominal concentration of 15 µg/g, and a positive control treatment dosed with both a nominal 15 µg/g of test substance plus 3 µg/g of hexachlorobenzene (HCB) were used. An uptake period of 14 days was followed by 56 days of depuration during which the fish were fed non-dosed food. Chemical analysis was performed using APCI-QToF-HRMS. The growth-corrected depuration half-life was 108.9 days and the growth-corrected and lipid-normalised kinetic biomagnification factor (BMF_{KgL}) was 0.468 (Unpublished, 2019e). As shown in Environment Agency (2019), the 15 models within the OECD TG 305 BCF estimation tool (OECD 2017a) all predict that the BCF significantly exceeds 5 000 L/kg. For HCB (positive control), the growth-corrected depuration half-life was 26 days and the BMF_{KgL} was 1.41. The study is assessed to be reliable without restrictions. As stated in the OECD guidance for the TG 305 '*it has been recognised that regulatory trigger values based on BCF (e.g. 2 000 or 5 000 L/kg) do not necessarily correspond to dietary BMFs from the dietary study greater than 1, especially in very small fish in the exponential phase of growth*' (OECD 2017b).

For example Inoue *et al.* (2012) performed a regression of analysis comparing measured laboratory dietary BMFs and BCFs for nine bioaccumulative substances and found that a BCF value of 5 000 L/kg corresponded to a dietary BMF_{KgL} of around 0.3 in juvenile carp (*Cyprinus carpio*).

45. Several more studies provide information about fish bioaccumulation for other relevant constituents, as summarised in Table 4. These are considered to be of lower reliability than the two studies summarised above.

Table 4: Results of additional fish bioaccumlation studies of lower reliability

<table>
<tr><th rowspan="2">Chlorine content,% w/w</th><th colspan="5">Carbon chain length</th></tr>
<tr><th>C_{14}</th><th>C_{15}</th><th>C_{16}</th><th>C_{17}</th><th>C_{18}</th></tr>
<tr><td><40</td><td></td><td></td><td>>5 000 L/kg (extrapolated from a dietary test) Fisk et al., 1996</td><td></td><td></td></tr>
<tr><td>40 - 45</td><td rowspan="3">>5 000 L/kg (extrapolated from a dietary test) Fisk et al., 1998b#</td><td></td><td></td><td></td><td></td></tr>
<tr><td>45 - 50</td><td></td><td></td><td></td><td>>5 000 L/kg (extrapolated from a dietary test) Fisk et al., 2000</td></tr>
<tr><td>50 - 55</td><td>2 072 L/kg* Thompson et al., 2000</td><td></td><td></td><td></td></tr>
<tr><td>55 - 65</td><td>>5 000 L/kg (extrapolated from a dietary test) Fisk et al., 2000</td><td></td><td></td><td></td><td></td></tr>
<tr><td>>65</td><td></td><td></td><td>>5 000 L/kg (extrapolated from a dietary test) Fisk et al., 1996</td><td></td><td></td></tr>
</table>

Note: # May be unreliable. * Not lipid corrected.

46. The bioaccumulation of a C_{15} chlorinated n-alkane, 51% Cl wt. substance in Rainbow Trout (*O. mykiss*) was measured by Thompson *et al*. (2000). This was a

GLP study performed according to OECD TG 305. It used flow-through exposure and a ^{14}C radiolabelled test substance. Two test concentrations (nominally 1 µg/L and 5 µg/L) were used, although the higher concentration was considered to have exceeded the water solubility as lower BCF values were determined. Fish lipid content was not measured so lipid normalisation is not possible. BCF values were calculated based on total radioactivity in fish and mean-measured water concentrations. The growth-corrected kinetic BCF for the low concentration was 2 072 L/kg, and the growth corrected depuration half-life was 29 days. While the BCF value is significantly lower than for a lower chlorine content C_{14} substance (see paragraph 44), the depuration half-life suggests significant concern for bioaccumulation (a depuration half-life around 8 to 10 days is indicative of a lipid-normalised and growth-corrected BCF above 5 000 L/kg according to the analysis in Environment Agency (2012) and discussed in OECD (2017b)). The apparent and unexplained disparity between BCF value and depuration half-life indicates that the test results should be treated with caution. It is considered to be a supporting study.

47. Fisk *et al*. (1996, 1998b and 2000) performed a series of fish dietary bioaccumulation studies using Rainbow Trout (*O. mykiss*) from which BCF values can be derived using the OECD estimation tool (OECD, 2017a). These used C_{14} (in two separate studies), C_{16} and C_{18} chain lengths with varying chlorination levels[8], some of which were run together in the same experiment. The test substances were specifically synthesised and had chlorine atoms on the terminal carbon atoms (which could have affected metabolic potential). The tests were not conducted to a standard test guideline or GLP, and key information to validate the studies run in 1996 and 1998 is not available. In particular Fisk *et al*. (1998b) may be unreliable as key details regarding feeding rate, feed husbandry and fish replicate numbers are not provided. Although several important aspects are missing for the Fisk *et al*. (2000) study (e.g. demonstrating food homogeneity, measurement of oxygen content and water temperature), information about other key aspects of the study (e.g. control validity and consistency of test substance uptake) suggests that it was likely to have been adequately performed. The chemical analysis in all of the tests used suggests that measurements would have been semi-quantitative, so some caution is needed regarding the exact results. It is also not possible to check the raw data used for the growth correction or lipid normalisation that was performed. Overall, these studies are assessed to be of unknown reliability. The results from these studies indicate that depuration half-lives were between 29 and 91 days, with estimated BCF values exceeding 5 000 L/kg for all constituents. The C_{18} result suggests that a similar result would have been seen if a C_{17} constituent had been tested.

48. Collectively the four laboratory studies (Fisk *et al*. (1996, 1998b and 2000) and Thompson *et al*. (2000)) are considered to indicate that constituents with carbon

[8] $C_{14}H_{26}Cl_4$ 42% Cl wt.; $C_{14}H_{25}Cl_5$ 48% Cl wt. (two different isomers); $C_{14}H_{24}Cl_6$ 53% Cl wt. (two different isomers); $C_{14}H_{23.3}Cl_{6.7}$ 55% Cl wt.; $C_{16}H_{31}Cl_3$ 35% Cl wt. (two different isomers); $C_{16}H_{21}Cl_{13}$ 69% Cl wt. (three different isomers); $C_{18}H_{31.4}Cl_{6.6}$ 48% Cl wt.

chains longer than C_{14} may have significant bioaccumulation potential in fish, but this cannot be reliably confirmed. They are considered to be supporting studies.

5.3.3. Other aquatic taxa of potential concern

49. Castro *et al*. (2019) determined BCF values considerably above 5 000 L/kg for a C_{13}-C_{18} chlorinated n-alkane (45% Cl wt.) substance in a non-standard, non-GLP laboratory bioaccumulation study using the water flea *Daphnia magna*. However, there is significant uncertainty for the result due to the single water concentration measurement and use of dry weight rather than wet weight animal concentration measurements.

50. Renberg *et al*. (1986) and Madeley & Thompson (1983) used a $C_{14\text{--}17}$ chlorinated n-alkane (52% Cl wt.) and a C_{16} chlorinated n-alkane (34% Cl wt.) in non-standard, non-GLP bioaccumulation tests using Blue Mussel *Mytilus edulis*. The bioaccumulation factors (BAFs) exceeded 2 000 L/kg and 5 000 L/kg, respectively. The age of these two studies, together with the use of nominal exposure concentrations exceeding the water solubility (making unclear if the resulting BAF is over or under-estimated when adsorption to food is taken into account) means that their reliability is considered to be low.

51. These three studies are not considered sufficiently reliable to support the proposal, but they do indicate a concern that other aquatic taxa besides fish may experience high bioaccumulation of CPs with $C_{14\text{-}17}$ chain lengths

52. A biota-sediment accumulation factor (BSAF) of 4.4 on a lipid-normalised basis was determined for a C_{16} chlorinated n-alkane, 35% Cl wt. in a study using the sediment-dwelling oligochaete *Lumbriculus variegatus*; the BSAF for a C_{16} chlorinated n-alkane, 69% Cl wt. substance was 0.6 (Fisk *et al*., 1998a). As the gut contents of the organisms were not purged prior to analysis, the bioaccumulation could be significantly overestimated, and therefore the study results are considered to be of low reliability.

53. In summary, laboratory bioaccumulation studies using fish indicate high levels of bioaccumulation for different constituents of CPs with $C_{14\text{-}17}$ chain lengths. In particular, reliable aqueous and dietary exposure studies for C_{14} chain lengths with chlorine contents in the range 45-50% Cl wt. have measured or extrapolated BCF values above 5 000 L/kg. Several other fish bioaccumulation studies of lower reliability suggest BCF values ranging from around 2 000 L/kg to above 5 000 L/kg for carbon chains longer than C_{14}. Other available laboratory bioaccumulation data for invertebrates are less reliable but suggest that the concern for high bioaccumulation may not be limited to fish.

5.3.4. Field biomagnification and monitoring studies

54. The Swedish Environmental Protection Agency (1998) found no evidence for biomagnification in a fish (*Clupea harengus*) to seal (*Halichoerus grypus*) food chain for CPs based on the results of Jansson *et al*. (1993) (the levels found in the fish were higher than in seals by an order of magnitude on a lipid weight basis). The actual CPs determined in the Jansson *et al*. (1993) study were of unspecified

carbon chain length, with between 6 and 16 chlorine atoms per molecule, and so may have included CPs other than C_{14-17}. Due to the age of the study, and analytical methods available at that time, the results should be treated with caution.

55. Muir *et al*. (2002) found no indication of biomagnification in three Lake Trout (*Salvelinus namaycush*) – fish food chains, but did suggest BMFs above 1 for "MCCPs" in a fish – invertebrate food chain. Furthermore, there were some indications that the actual bioaccumulation seen in fish was higher than would be expected by bioconcentration processes alone (although it should be noted that there is considerable uncertainty in these data).

56. A similar study (possibly including some of the same information as Muir *et al*., 2002) was published by Houde *et al*. (2008). In this study C_{14}, C_{15}, C_{16} and C_{17} CP levels were determined in samples of biota collected in Lake Ontario and northern Lake Michigan, North America between 1999 and 2004. The data were presented as mean concentrations over the period 1999 to 2004. The highest average concentrations were found in Slimy Sculpin (*Cottus cognatus*), and Rainbow Smelt (*Osmerus mordax*) (0.11 mg/kg). When "MCCPs" was detected, C_{14} CPs were the predominant constituents found in samples from Lake Michigan. However, samples from Lake Ontario generally showed that C_{15} constituents were present at similar, and in several cases higher, concentrations than the C_{14} constituents in those samples. An indication of potential variability is that the mean concentration of "MCCPs" in Lake Trout from Lake Ontario reported by two different papers was 25 µg/kg in 1998, 15 µg/kg in 2001 and 8 µg/kg in 2004 (Muir *et al.*, 2002; Ismail *et al*., 2009).

57. Houde *et al*. (2008) compared these biota concentrations with the mean level of "MCCPs" determined in water samples from 2004 (0.9 pg/L). Based on these results, lipid normalised BAFs (expressed as log BAF_{lipid}) for C_{14} and C_{15} CPs were determined as 6.2 and 6.6 in plankton, 7.0 and 6.8 in Alewife (*Alosa pseudoharengus*), 7.4 and 7.2 in Slimy Sculpin (*Cottus cognatus*), 7.4 and 7.1 in Rainbow Smelt (*Osmerus mordax*) and 6.8 and 6.5 in Lake Trout (*S. namaycush*), respectively. Again the lipid-normalised BMF values for total "MCCPs" were below 1 in food chains consisting of Lake Trout – Alewife (BMF 0.22 - 0.25), Lake Trout – Rainbow Smelt (BMF 0.14) and Lake Trout – Slimy Sculpin (BMF 0.11 - 0.94). The lipid-normalised BMF was above 1 for the Slimy Sculpin – *Diporeia* food chain in Lake Ontario (BMF 8.7), but below 1 in the same food chain from Lake Michigan (BMF 0.88). It was noted that the BMF for Slimy Sculpin – *Diporeia* in Lake Ontario was based on the detectable concentration in one sample only. Trophic magnification factors (TMFs) were determined to be in the range 0.06 to 0.36 for fourteen individual constituents in the C_{14} to C_{16} chain length range for the Lake Ontario food chain (a similar analysis could not be carried out for Lake Michigan samples), suggesting trophic dilution was occurring overall. When considering these data it should be noted that the water concentrations relate to samples collected in 2004 whereas the biota samples were taken between 1999 and 2004. No information was provided about how the dissolved concentration in water varied between 1999 and 2004 and so this means that the reported BAFs in particular are highly uncertain.

58. Du *et al*. (2018) investigated the occurrence of CPs in wildlife from paddy fields in the Yangtze River Delta, China. Nine species (2 fish, 3 reptiles, 1 mammal and 3 birds) were sampled: Pond Loach (*Misgurnus anguillicaudatus*), Rice Field Eel (*Monopterus albus*), Red-backed Rat-snake (*Elaphe rufodorsata),* Short-tailed Mamushi Snake (*Gloydius brevicaudus*), Red-banded Snake (*Dinodon rufozonatum*), Yellow Weasel (*Mustela sibirica*), Peregrine Falcon (*Falco peregrinus*), Collared Scops-owl (*Otus lettia*) and Common Cuckoo (*Cuculus canorus*). Numerical values are provided in Appendix 5. The highest values were found in snakes, the weasel and predatory birds (up to 33 mg/kg lipid weight (lw) or 4.7 mg/kg dw). The authors found that the average concentrations were in the order "MCCPs" > SCCPs > LCCPs, except in birds where SCCPs were found to be more abundant. "MCCPs" appears to be widely dispersed in wildlife at the sampling locations. The concentrations refer to specific tissues (rather than whole body), the sampled species were not necessarily part of the same food web, and there is no information about dietary concentrations. It is therefore not possible to draw firm conclusions about trophic magnification from this study.

59. In a related study to Du *et al*. (2018) by the same research group, Zhou *et al*. (2019) investigated the occurrence of CPs in aquatic wildlife from Lake Dianshan in the Yangtze River Delta, China. Nine species were sampled: Snakehead (*Channa argus*), Bigmouth Grenadier Anchovy (*Coilia ectenes*), Yellow Catfish (*Pelteobagrus fulvidraco*), Grass Carp (*Ctenopharyngodon idella*), Crucian Carp (*Carassius auratus*), Predatory Carp *(Erythroculter ilishaeformis*), Common Carp (*Cyprinus carpio*), a snail (*Bellamya aeruginosa*) and a clam (*Corbicula aurea*). "MCCPs" concentrations in fish were up to 3.1 mg/kg lw, which is similar to concentrations in the fish (up to 4 mg/kg lw) sampled in the paddy fields by Du *et al*. (2018). It should be noted that a limited number of fish were sampled in the lake (a single animal per species, aside from anchovy). Concentrations in clams and snails were at a similar order of magnitude to the fish.

60. Du *et al.* (2019, 2020) conducted two further studies sampling and analysing CP in biota in the paddy fields of the Yangtze Delta. In the first study, pooled muscle, liver and unfertilised egg samples of the Black-spotted Frog (*Pelophylax nigromaculatus*, n = 69) were analysed with "MCCPs" concentrations between the detection limit and 50 ng/g ww (Du *et al.*, 2019). In the second study pooled muscle, liver and adipose tissues from two snake species – the terrestrial Short-tailed Mamushi (*Gloydius brevicaudus*, n=7) and the semi-aquatic Red-backed Rat Snake (*Elaphe rufodorsata,* n = 9) – were analysed with "MCCPs" concentrations between 0.17 and 14.0 mg/kg lw (Du *et al.*, 2020). The dominant MCCP homologue was C_{14}. Congener specific analysis indicates differences in uptake in the tissues, but a range of congeners were detected in all the animals. Du *et al.* (2020) calculated mean BMF values for "MCCPs" of 1.8 (maximum BMF 2.8) in the Black-spotted Frog – Red-backed Rat Snake food chain based on muscle concentration (3.1 and 5.5 mg/kg lw). According to ECHA (2021a), both species were sampled at the same times and place in 2011. The analysis appears to have been performed recently. Measurement of $\delta^{13}C$ and $\delta^{15}N$ indicates that the two species were part of the same food chain. As the BMFs were tissue-specific calculations (not whole

body), a low number of snakes were sampled, and it is not possible to verify that the snakes exclusively ate frogs. There is therefore uncertainty in the reliability of the reported BMFs, and they are assigned a low weight for the purposes of this proposal. Nevertheless, the study indicates the possibility of biomagnification.

61. Liu *et al*. (2020) studied the biomagnification of "MCCPs" in a terrestrial food web covering 7 species of insect, 2 amphibians, 1 lizard and several insectivorous birds. Biota were sampled over 14 months across an area where e-waste recycling and farming were taking place in Guangdong Province, south China. The calculated TMF for the insect – amphibian/lizard food chain for the sum of "MCCPs" was 2.45. A significant, positive correlation was noted between $\delta^{15}N$ and the percentage chlorination of "MCCPs". This suggests that higher biomagnification potential was linked to higher levels of chlorination. The paper provides evidence that the amphibians were in the same food chain as the insects. However, the numbers of amphibians and lizards sampled are low compared to the number of insects, BMFs were calculated from predator muscle tissue but insect whole body, sampling took place at different times over more than one year, and the range of trophic levels occupied by single predator species (1.7 to 3.8) was higher than expected (so birds were excluded from the TMF calculations). There is therefore uncertainty in the derived TMF values, which are assigned a low weight for the purposes of this proposal.

62. Wang *et al.* (2021) evaluated the environmental fate of CPs in a constructed wetland ecosystem in Beijing Olympic Forest Park, China. The wetland is a series of interlinked ponds designed to purify contaminated water that is "mostly" from the Beijing Qinghe Water Reclamation Plant (which receives only domestic wastewater). Water, sediment and three types of plant (5 emergent, 4 floating and 2 submerged plants, all specifically planted to absorb chemical contaminants) were sampled from different parts of the system, in parallel with water and sediment sampled four times over one month. Total "MCCPs" concentrations in the plants were in the range 21 to 785 µg/kg dw (mean 289±148 µg/kg dw). Concentrations measured in the different plant types were similar. The authors calculated BCFs for each plant type using the measured water and plant tissue concentrations. From visual inspection of two graphs in the paper, the median BCF values for C_{14-17} chain lengths in the floating plants (*Nymphaea tetragona, Lemna minor, Enteromorpha prolifera,* and *Brasenia schreberi*) were either up to 3 000 or 13 000, but the values for specific species are not provided[9]. These values may be considerably overestimated as the dry weight concentration of CPs in plant material were used. Furthermore, since both submerged and emergent plants (and one of the floating plants (*Nymphaea tetragona*)) are rooted in the sediment, a BSAF value may be more relevant for many of these plants. Hydraulic retention in the system was indicated to be around 10 days. It is not certain whether the measured contaminant concentrations in water/sediment are representative of the

[9] There are two graphs of BCF values covering different but overlapping ranges of carbon chain lengths, providing contradictory BCF values for "MCCPs" carbon chain lengths.

concentrations the plants will have been exposed to over a longer time period. Despite the uncertainties, the results suggest that “MCCPs” are bioavailable to aquatic plants.

63. Zeng *et al.* (2017b) collected 4 mollusc species, 7 crustacean species, and 16 fish species from the subtropical Hong Kong waters of the South China Sea and analysed these for “MCCPs”. These values were then compared to average concentrations of the CPs in blubber from two cetacean species: 12 Finless Porpoise (*Neophocaena phocaenoides*, 5.5 mg/kg lw) and 3 Indo-Pacific Humpback Dolphins (*Sousa chinensis*, 47 mg/kg lw) sampled in the same year and region and detailed in an earlier paper (Zeng *et al*., 2015). BMFs and TMFs were calculated using the fish muscle tissue, the mollusc soft tissue and the cetacean blubber concentrations (all lipid weight). Calculated BMF and TMF values exceed 1. While the concentrations in the mammals are notably higher than the prey, there is considerable uncertainty for whether the mammals exclusively consume the prey in the sample area or would have also consumed prey from a wider – and possibly more contaminated – area (for example the dolphin is indicated to prefer feeding in brackish estuarine waters, which would appear to be some distance from the prey sampling site). Further uncertainty results from the low sample numbers of the predators; the use of a single pooled value for each predator in the TMF calculation; and the use of tissue rather than whole body concentrations. Therefore the BMF and TMF values are not considered to be reliable. Nevertheless, the high average concentrations observed in the cetaceans’ blubber suggest the possibility of high bioaccumulation resulting from exposure to “MCCPs”.

64. Yuan *et al*. (2019) analysed for CPs with a chain length up to C_{30} in the Swedish environment using APCI-QToF-MS. Numerical values are provided in Appendix 5. In the marine food web, concentrations of $C_{14\text{-}17}$ congeners in White-tailed Sea-eagles (*Haliaeetus albicilla*), Grey Seal (*Halichoerus grypus*), Harbour Seal (*Phoca vitulina*) and Harbour Porpoise (*Phocoena phocoena*) (around 0.2 to 0.5 mg/kg lipid) were generally similar to or higher than those in Herring (*Clupea harengus*) (around 0.03 to 0.44 mg/kg lipid). The concentrations refer to specific tissues (rather than whole body), the sampled species were not necessarily part of the same food web, and there is no information about other dietary concentrations. It is therefore not possible to draw firm conclusions about trophic magnification from the data collected in this study.

65. Casa *et al.* (2019) analysed for “MCCPs” in blubber samples obtained from nine Humpback Whale (*Megaptera novaeangliae*) specimens. The whales stranded between 2007 and 2015 in western and eastern Australia. Genetic testing indicated that the whales were associated with two Antarctic Management Areas, and principally feed on Antarctic Krill (*Euphasia superba*). This population migrates seasonally to equatorial breeding grounds, and during migration individuals rely on the energy reserves accumulated through summer feeding in Antarctica. As such the authors expect the chemical profiles of this population to reflect their krill diet. The paper has very little information about “MCCPs”. Unsatisfactory analytical recoveries were obtained for the “MCCP” congeners (53%), but “MCCPs” were detected in three of the nine samples above the method detection limit of 33 ng

absolute mass (no further information is available). The three detections corresponded to blubber samples from one adult and two juvenile whales.

66. Bennie *et al*. (2000) reported levels of "MCCPs" up to around 80 mg/kg wet weight (ww) in blubber samples from stranded Beluga Whales (*Delphinapterus leucas*) from the St. Lawrence River, Canada, although the analytical method may have been affected by the possible presence of co-eluting interfering organochlorine substances[10].

67. Reth *et al*. (2006) found "MCCPs" to be present in liver and muscle samples from two Arctic Char (*Salvelinus alpinus*), two Little Auk (*Alle alle*) and two Black-legged Kittiwake (*Rissa tridactyla*) specimens collected from the Arctic. The highest concentration was 0.37 mg/kg (in auk liver tissue). The very small sample size used in this study means that limited weight should be placed on the findings, although it demonstrates that "MCCPs" are present in Arctic biota.

68. Several studies have indicated that "MCCPs" can undergo maternal transfer to birds' eggs, the highest reported concentration being 0.135 mg/kg ww (e.g. Heimstad *et al*., 2018; Ruus *et al*., 2018; Green *et al*., 2018; Yuan *et al*., 2019).

5.3.5. Terrestrial organisms

69. An earthworm-soil accumulation factor of 2.4 for adults and 2.3 for juveniles was determined for a C_{15} chlorinated n-alkane, 51% Cl wt. in a 56-day study using *Eisenia fetida* (Thompson *et al*., 2001). This is assessed to be reliable with restrictions.

70. Yuan and de Wit (2018) and Yuan *et al*. (2019) analysed for CPs with a chain length up to C_{30} in the Swedish environment using APCI-QToF-MS. Numerical values are provided in Appendix 5. For the terrestrial species sampled between 2012 and 2017, Bank Voles (*Myodes glareolus*) were found to contain the lowest amounts of $C_{14\text{-}17}$ congeners. The detected concentrations of $C_{14\text{-}17}$ congeners in muscle were comparable in Eurasian Lynx (*Lynx lynx*) and Grey Wolf (*Canis lupus*) (0.75 to 0.83 mg/kg lipid), whilst Moose (*Alces alces*) muscle contained the highest concentrations (1.6 mg/kg lipid). $C_{14\text{-}17}$ congeners were also detected in muscle or eggs of terrestrial birds of prey (Tawny Owl (*Strix aluco*), Eagle Owl (*Bubo bubo*), Marsh Harrier (*Circus aeruginosus*), Golden Eagle (*Aquila chrysaetos*) and Peregrine Falcon (*Falco peregrinus*)) up to 0.72 mg/kg lipid. The concentrations refer to specific tissues (rather than whole body), the sampled species were not necessarily part of the same food web, and there is no information about other dietary concentrations. It is therefore not possible to draw firm conclusions about trophic magnification from the data collected in this study.

[10] A gas-chromatography-low resolution negative ion mass spectrometry method was used. Although no comparison was carried out for "MCCPs", Bennie *et al.* (2000) compared their results for SCCPs with those obtained on Beluga Whale samples using a gas-chromatography-high resolution negative ion mass spectrometry method from another study. They found that the concentrations were one to two orders of magnitude *lower* using the high resolution method than the low resolution method.

5.3.6. Mammalian data relevant to bioaccumulation

71. Laboratory data for mammals were assessed in EC (2007). Mammalian studies using radiolabelled “MCCPs” have shown that absorption following oral exposure is significant (probably at least 50% of the administered dose; however, the concentration reached in the organism is generally lower than that in food). Following absorption there is an initial preferential distribution of the radiolabel to tissues of high metabolic turnover/cellular proliferation. Subsequently there is a re-distribution of radiolabel to fatty tissues where half-lives of up to 8 weeks have been determined for abdominal fat. Of special interest is the study by CXR Biosciences Ltd (2005a) that found that a steady state concentration in white adipose tissue was reached after approximately 13 weeks’ dietary exposure. The elimination from this tissue was found to be biphasic with an initial half-life of 4 weeks followed by a much slower elimination.

72. Dong *et al*. (2020) extrapolated results from a rat PBPK (physiologically-based pharmacokinetic) model to a human PBPK model. Based on a comparison of volumes of distribution and half-lives, CPs were predicted to accumulate in the liver and fat. The authors estimated the half-life of “MCCPs” in humans to be 1.2 years, which is much longer than in rats.

73. Greenpeace (1995) analysed human breast milk for “MCCP” content using pooled samples from six individuals (who ate fish at least once a week) and two non-fish-eaters (who ate fish a maximum of once a month). Similar results were obtained for both groups. The mean “MCCPs” concentration was 50.4 µg/kg lw in the fish-eating group, compared to 40.5 µg/kg lw in the non-fish-eaters; the low sample size meant that it was not possible to determine if any significant differences were apparent between the two groups.

74. Thomas and Jones (2002) detected “MCCPs” in 1 out of 22 samples of human breast milk from the UK, at 61 µg/kg lipid, although the analytical detection limit was relatively high. A follow-up study (Thomas *et al*., 2006) detected “MCCPs” in all 25 samples of human breast milk at 6.2 to 320 µg/kg lw (median 21 µg/kg lw).

75. C_{14} CPs were found to be the predominant constituents of “MCCPs” present in samples of human breast milk from Bavaria (Hilger *et al*., 2011). MCCPs were detected in 58% of samples (n=60), with a range of 9.6 to 903 µg/kg lw.

76. Darnerud *et al*. (2012) reported CP concentrations in human breast milk from samples collected between 1996 and 2010 in Uppsala County, Sweden. The mean “MCCP” concentration was 14.4 ng/g lw, although large variation between pools from different years was observed. The authors noted that their MCCP concentrations were comparable to those from the UK (Thomas *et al*., 2006).

77. Xia *et al*. (2017a) found “MCCP” concentrations in pooled samples of human breast milk collected from rural China ranged from 9.05 to 139 µg/kg lw (median 35.7 µg/kg lw) in 2007, and between 9.51 and 146 µg/kg lw (median 45.4 µg/kg lw) for samples taken in 2011. C_{14} homologues comprised 82% of the total “MCCP” content. In a further study of samples of human breast milk from urban locations in China at the same time points, Xia *et al*. (2017b) found “MCCP” concentrations

ranged from 18.7 to 350 µg/kg lw (median 60.4 µg/kg lw) in 2007, and between 22.3 and 1501 µg/kg lw (median 137 µg/kg lw) for samples taken in 2011. Good correlation in the urban study was noted between areas with higher CP breast milk concentrations and areas of higher CP production (Xia *et al*., 2017b).

78. Zhou *et al.* (2020) detected CPs using APCI-QToF-HRMS in human breast milk sampled from three cities in the Yangtze Delta of China, a city in Sweden and one in Norway. “MCCPs” were found in most samples, with concentrations ranging from below the detection limit to 1 260 µg/kg lw (median 78.8 µg/kg lw) for the Chinese samples, and from below the detection limit to 311 µg/kg lw (median 29.6 µg/kg lw) for the Scandinavian samples.

79. The European Food Safety Authority summarised the available information on levels of CPs in human samples collected in Europe, Asia (mainly China) and Australia (EFSA, 2020). “MCCPs” have been detected in human milk samples, with levels generally being lower in the few European studies than in samples collected in Asia. EFSA (2020) quotes levels of “MCCPs” between < 5.5 to 112 µg/kg lw in human breast milk across 11 European countries.

80. Li *et al.* (2017) determined the concentration of CPs in all 50 human blood samples taken from the general population in Shenzhen, China. The “MCCP” concentrations were reported as being between 130 and 3 200 µg/kg lw. The relative exposure of the participants is unknown. “MCCPs” were also detected in human blood and human placenta samples from China by Wang *et al.* (2018), with concentrations ranging from 80.8 to 954 µg/kg lw.

5.3.7. Bioaccumulation synthesis

81. The constituents of CPs with $C_{14\text{-}17}$ chain lengths have a range of log K_{OW} values, but all measured values exceed 5.

82. Two reliable fish bioaccumulation studies conducted according to OECD TG 305 and to GLP show that a C_{14} chlorinated n-alkane, 45% Cl wt. product has a measured BCF value significantly in excess of 5 000 L/kg in Rainbow Trout (*Oncorhynchus mykiss*), and that a C_{14} chlorinated n-alkane, 50% Cl wt. substance has a calculated BCF from dietary exposure significantly in excess of 5000 L/kg.

83. Supporting laboratory evidence indicates that there may be a high bioaccumulation potential in fish for CPs with chain lengths longer than C_{14}. They are an aqueous exposure test performed with a C_{15} chlorinated n-alkane, 51% Cl wt. substance and a series of dietary bioaccumulation studies using C_{14}, C_{16} and C_{18} chain lengths with different levels of chlorination. The measured and estimated BCF values range from around 2 000 L/kg to above 5 000 L/kg. Additionally, all substances had long depuration half-lives (consistent with a BCF exceeding 5 000 L/kg). Invertebrate data also suggest that other taxonomic groups might bioaccumulate $C_{14\text{-}17}$ CPs significantly. However, these studies are all of lower and mixed reliability and are therefore considered to carry a lower weight in this assessment.

84. Despite the general uncertainty in the available aquatic and terrestrial monitoring data due to the analytical challenges described in paragraph 166, CPs with C_{14-17} chain lengths are present (often based on the detection of “MCCPs”) in a wide range of organisms living and feeding in locations that are close to input sources (i.e. industrial and urban areas). Whilst more limited in number, “MCCPs” have also been detected in samples from remote regions, including the Arctic, as well as in top predators. Only limited information is available on the actual carbon chain length distribution and chlorine contents of “MCCPs” detected in most environmental samples, although advances in analytical methodologies have meant that this has been possible in some of the more recent studies. C_{14} chain lengths are frequently the predominant constituents of “MCCPs” when more detailed information is available. This chain length is a significant constituent of commercial product types (see paragraph 6), and in other environmental media such as sediment (Hüttig and Oehme, 2006).

85. Monitoring studies demonstrate widespread contamination of wildlife by CPs with C_{14-17} chain lengths at all trophic levels (including predatory species). The available (limited) field bioaccumulation studies are equivocal: TMFs below and above 1 have been derived for “MCCPs”, and although most BMFs are below 1, BMF values above 1 have been derived for some specific feeding relationships. The data collected in more recent studies, while still limited, do not contradict the possibility of bioaccumulation up the food chain. It should be noted that all of the available field magnification studies have methodological limitations.

86. “MCCPs” are detected in human breast milk, and other tissue such as blood, with the substance estimated to have a long half-life in humans.

87. Overall, the Annex D criteria for bioaccumulation 1c(i) are considered to be met as BCF values exceed 5 000 L/kg for at least the C_{14} constituents with a chlorination level in the range 45-50%. Less reliable data suggest that the C_{15-17} constituents may also meet the criteria. This is supported by monitoring data for “MCCPs” indicating widespread uptake by biota.

5.4. Potential for long-range environmental transport

5.4.1. Atmospheric half-life

88. No measured atmospheric half-lives are available for CPs with C_{14-17} chain lengths. AOPWIN v1.92 (US EPA, 2020) has been used to make predictions of the hydroxyl radical rate constant (k_{OH}) to estimate atmospheric half-lives. The model is based on a training set of 667 organic chemicals, of which 1-chlorohexane is the closest analogue to the chlorinated C_{14-17} structures. Two representative “MCCPs” constituents ($C_{14}H_{24}Cl_6$ (52.6% Cl wt.) and $C_{17}H_{29}Cl_7$ (51.6% Cl wt.)) have been modelled. The C_{14} congener was selected based on the available laboratory data for persistence and bioaccumulation, and a C_{17} congener with an equivalent chlorination level was chosen for comparison. For each congener, 2 constituents were modelled, one with a chlorine atom on a terminal carbon atom and the other with no chlorines on the terminal carbon atom. This was designed to investigate

the variation of degradation with the relative position of chlorine atoms in the chain. Using a hydroxyl radical concentration of 5 x 10^5 OH/cm^3 (ECHA, 2016[11]) atmospheric half-lives slightly above and slightly below 2 days (between 37 and 62 hours) were estimated from the predicted k_{OH}. These estimates should be treated with caution, as the closest chlorinated alkane in the model training set is a C_6 alkyl substance with a single chlorine atom, and there are no measured data with which to directly compare the current estimates. For a given chain length, increasing the chlorination level decreases the rate constant as fewer C-H bonds exist for reaction with the hydroxyl radicals. For a given chlorination level, increasing the chain length will increase the rate constant as more C-H bonds are available for reaction. This can also be seen in the half-lives for SCCPs, where estimated atmospheric half-lives ranged between 1.2 to 15.7 days (28.8 h to 377 hours) (UNEP, 2015). The high adsorption of CPs to atmospheric particles at low temperatures, typical of conditions at high latitudes, may also limit the atmospheric oxidation pathway.

89. Li *et al.* (2014) reported predicted hydroxyl rate constant values for 9 SCCP congeners and half-life values in the atmosphere. They developed a density functional theory (DFT) method for predicting k_{OH} values for 6 CPs through comparison with experimental values. Comparing the k_{OH} values for 9 SCCPs reported by Li *et al.* (2014) with those predicted from AOPWIN v1.92, the resulting AOPWIN v1.92 half-life predictions are lower for 6 of the SCCPs, higher for 2 SCCPs and similar for 1. For the 6 SCCPs where AOPWIN v1.92 predicted a lower value in air than Li *et al.* (2014), the difference in the two methods broadly increased with percentage chlorination. The biggest difference between predictions was noted for 1,1,1,2,3,9,11,11,11-nonachloroundecane at 68.4% chlorination. This comparison suggests that it is possible that AOPWIN v1.92 may under-predict atmospheric half-life values for “MCCP” congeners.

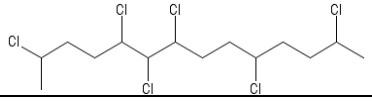
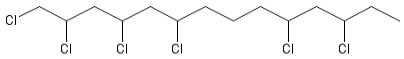
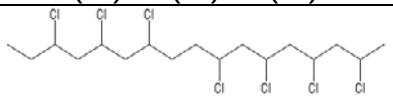
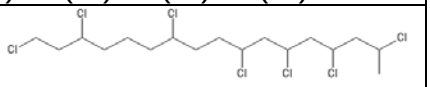
5.4.2. Modelling of Long Range Transport Potential

90. The OECD P_{OV} & LRTP Screening Tool (OECD, 2006) has been used to estimate the long-range transport potential (LRTP) of the four representative C_{14} and C_{17} constituents with predicted atmospheric half-lives described in the previous section. The input parameters for these constituents are shown in Table 5, which rely on physico-chemical values predicted by EPI Suite™ (US EPA, 2020). There may be some uncertainty as Environment Agency (2019) notes that EPI Suite™ might not be the most appropriate model to estimate physico-chemical values for CPs. This is considered in a sensitivity analysis in Appendix 4.

Table 5: Input (predicted) values for four C_{14-17} constituents (“MCCPs”) used to predict their LRTP

Parameters	**C_{14} constituent (52.6% Cl wt.)**	
OECD LRTP ID	**MCCP-1 (non-terminal**	**MCCP-2 (terminal**

[11] The value used is taken from ECHA (2016), rather than the hydroxyl concentration used within the AOPWIN model. The selected value (5 x 10^5 OH/cm^3) may not be typical of northern latitudes since hydroxyl radical concentrations decline with latitude.

	chlorine)	**chlorine)**
SMILES	CC(Cl)CCC(Cl)CCC(Cl)C(Cl)C(Cl)CCC(Cl)C	ClCC(Cl)CC(Cl)CC(Cl)CCCC(Cl)CC(Cl)CC
Structure		
Molecular mass (g/mol)	405.07	405.07
Molecular formula	$C_{14}H_{24}Cl_6$	$C_{14}H_{24}Cl_6$
Log K_{AW}	-0.64 (-2.0)#	-0.64 (-2.0)#
Log K_{OW}	8.3 (6.58)#	8.37 (6.58)#
Log K_{OA}	8.94 (8.58)#	9.01 (8.58)#
OH rate constant at 25 °C (cm^3/molecule-sec)	6.26×10^{-12}	8.02×10^{-12}
Half-life in air (h)*	61.5	48
Half-life in water (h)	4 320	4 320
Half-life in soil (h)	8 640	8 640
Parameters	**C_{17} constituent (51.6% Cl wt.)**	
OECD LRTP ID	**MCCP-3 (non-terminal chlorine)**	**MCCP-4 (terminal chlorine)**
SMILES	CC(Cl)CC(Cl)CC(Cl)CC(Cl)CCC(Cl)CC(Cl)CC(Cl)CC	ClCCC(Cl)CCCC(Cl)CCC(Cl)CC(Cl)CC(Cl)CC(Cl)C
Structure		
Molecular mass (g/mol)	481.5	481.5
Molecular formula	$C_{17}H_{29}Cl_7$	$C_{17}H_{29}Cl_7$
Log K_{AW}	-0.725	-0.725
Log K_{OW}	9.95	10.05
Log K_{OA}	10.68	10.78
OH rate constant at 25 °C (cm^3/molecule-sec)	9.58×10^{-12}	1.05×10^{-11}
Half-life in air (h)*	40.2	36.7
Half-life in water (h)	4 320	4 320
Half-life in soil (h)	8 640	8 640

Note: # Measured values (used in sensitivity analysis).

* Derived using a global annual average hydroxyl radical concentration of 5×10^5 molecule/cm^3.

91. The prediction results from the OECD screening tool for the four constituents are shown in Table 6.

Table 6: Predictions from the OECD screening tool for the four "MCCP" constituents

Predictions	C_{14} constituent (52.6% Cl wt.)		C_{17} constituent (51.6% Cl wt.)	
	Non-terminal chlorine (MCCP-1)	Terminal chlorine (MCCP-2)	Non-terminal chlorine (MCCP-3)	Terminal chlorine (MCCP-4)
Characteristic Travel Distance (CTD) (km)	1 276	998	1 041	1 003
Transfer Efficiency (TE) (%)	0.047	0.030	0.492	0.530
Overall persistence, P_{OV} (days)	511	512	519	519

92. To provide a comparison, data for SCCPs (which is already listed as a POP) have also been considered. SCCPs with >48% Cl wt. were the focus of the Risk Profile (UNEP, 2015). The LRTP modelling for this substance (referred to as "SCCP 5" below) used an atmospheric half-life value of 88.8 hours (Wegmann *et al*., 2007), although the specific congener modelled is not stated. Two further SCCP constituents have been modelled, with a chlorination level of 61%, which is considered to be representative of the typical 50% to 70% chlorination levels used for most commercial SCCP products (the input parameters are provided in Table 13 in Appendix 4). Similar to the MCCP modelling, the congeners are modelled with both terminal and no terminal chlorine atoms. These four constituents have predicted atmospheric half-lives between 84.7 and 144.3 hours. All five SCCP constituents have been run in the OECD P_{OV} & LRTP Screening Tool together with the four MCCP constituents. The results together with those for other available POP reference chemicals in the database (aldrin, a-HCH, HCB, PCB-28, PCB-101 and PCB-180) are shown in Figure 2. Figure 3 provides a zoomed extract of Figure 2 to show the CP positions. These indicate that the LRTP of "MCCPs" is similar to, but slightly less than, SCCPs. Given the lower atmospheric half-life predicted for the C_{14} and C_{17} constituents compared to SCCPs, this position is not surprising.

93. The high K_{OW} and low vapour pressure values of "MCCPs" suggests that it will strongly partition to organic matter, including adsorption into and onto aerosol particles in air, as well as to suspended solids in water. Long range transport of CPs with C_{14-17} chain lengths to remote regions is likely to be governed by sorption to particulates with subsequent deposition to soil, vegetation and water when conditions permit. CPs with C_{14-17} chain lengths are also likely to be transported via water while adsorbed to suspended particles.

94. The relative proportions of CPs with C_{14-17} chain lengths present in either the gaseous or particulate atmospheric phases has a strong influence on the potential for long range transport. For example, sorption to particulates reduces the potential for photodegradation during atmospheric transport relative to the gaseous phase. The high log K_{OA} value suggests that the proportion of CPs with C_{14-17} chain lengths

present in the gas phase is very low; the OECD tool predicts the fraction in aerosols in air to be between 0.85% and 28.4%. Within EPI Suite™ the AEROWIN v1.0 model has three methods for estimating the fraction sorbed to airborne particulates (phi) from the substance properties (US EPA, 2020). The phi values predicted by AEROWIN v1.0 for CPs with C_{14-17} chain lengths (1.68% to 63.8%) are higher than predicted by the OECD Tool. This implies that a lower proportion of the CPs with C_{14-17} chain lengths may be available for degradation in air than is predicted by the OECD Tool and therefore the long range transport potential in air is potentially underestimated. Phi values for "MCCPs" and SCCPs are discussed further in Appendix 4.

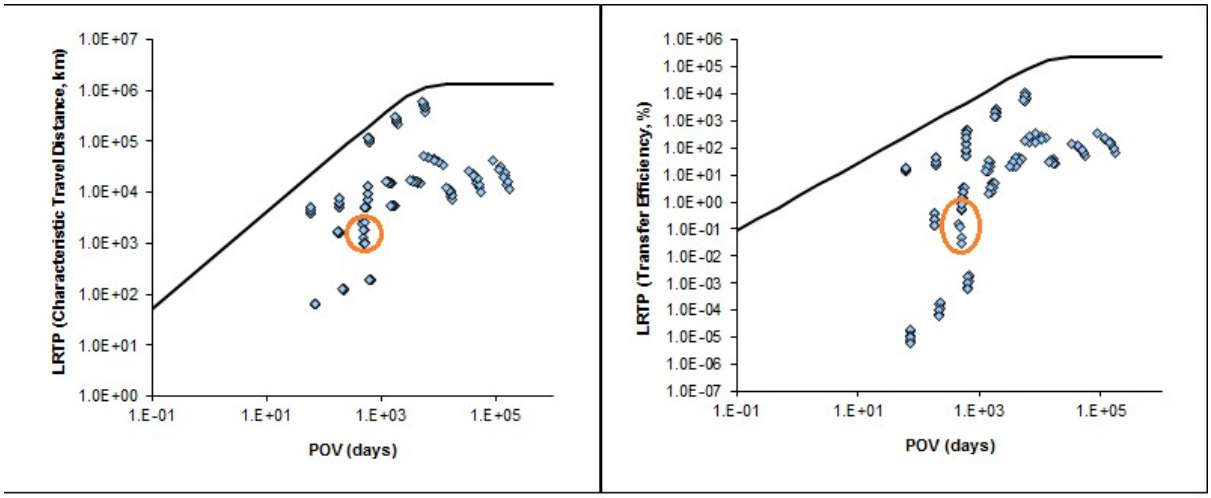


Figure 2: Output plots for CTD and TE for 4 MCCP and 5 SCCP constituents (within orange circle)

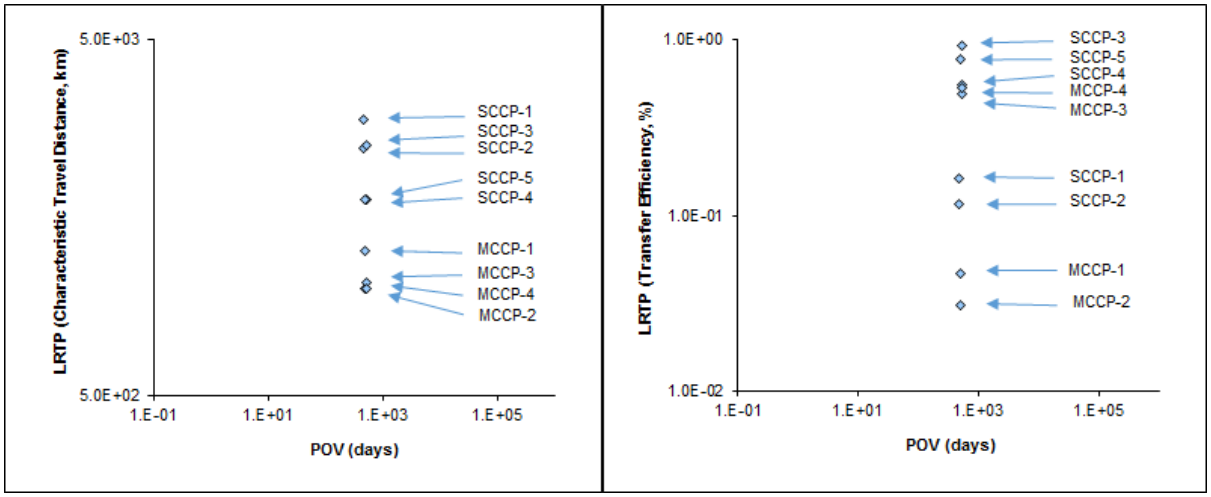


Figure 3: Output plots for CTD and TE for 4 MCCP and 5 SCCP constituents (expanded view of figure 2, with labelled constituents)

95. The absence of degradation in the OECD TG 308 study could be a result of strong binding to the sediment phase, and consequent lack of bioavailability. This adsorption would also then suggest the level of gaseous partitioning may be over-estimated by the OECD tool. Jiang *et al.* (2021) indicate that "MCCPs" detected in

Antarctica were present as 72.1% gas phase and 27.9% in the particle phase (based on 3 commercial products with 42%, 52% and 57% Cl wt. as the analytical standards). Greater partitioning of higher molecular weight CPs was shown by Al Saify *et al.* (2021) in air sampling development work using the same analytical standards, where "MCCPs" in the gaseous phase was exclusively 42% Cl wt., whereas more than half of the particle-bound "MCCPs" was composed of congeners with 52 to 57% Cl wt.

96. Gawor and Wania (2013) analysed predictions of log K_{AW} and log K_{OA} for a number of complex halogenated chemical mixtures, including CPs, to forecast their fate including LRTP. They suggest that substances with a log K_{OA} between 6.5 and 10 are "multiple hoppers" (which undergo repeated cycles of deposition and re-evaporation to reach higher latitudes). Substances with log K_{OA} ≥10 are likely to be "single hoppers" (sorbed to aerosols, which would need to undergo LRT without being deposited along the way in order to accumulate in remote locations like the Arctic). They expect "MCCPs with around 4 to >6 chlorine atoms" would be single hoppers based on the authors' prediction that log K_{OA} >10 (which was estimated using ACD labs software). Using experimental data (see Table 5) for the C_{14}, 51% Cl wt. constituent, a log K_{OA} of 8.58 can be estimated which suggests that the K_{OA} predicted by ACD labs is over-estimated for "MCCPs" and the experimental data suggests the C_{14} constituent would be a multiple hopper on the basis of the log K_{OA}.

97. The long-range atmospheric transport potential for CPs with $C_{14\text{-}17}$ chain lengths has also been assessed by Environment Canada (2008). They concluded that the atmospheric half-lives for vapour phase "MCCPs" ranged from 2.7 to 7.1 days (64.8 to 170.4 hours). The longest half-lives were for constituents with the highest chlorine contents and shorter chain lengths, although the specific constituents are not specified. The sensitivity of the OECD tool to this range of half-lives is shown in Table 14 in Appendix 4. It can be seen that CTD increases significantly and TE also increases with a longer half-life, but there is little change to P_{OV}. Environment Canada (2008) further concluded that "MCCPs" have estimated vapour pressures and Henry's Law constants in the range of values for several POPs that are known to undergo long-range atmospheric transport, such as lindane, heptachlor and mirex.

5.4.3. Air monitoring data

98. Several monitoring studies have reported the detection of "MCCPs" in the air of polar regions and other remote areas such as the high altitude Tibetan Plateau, which provides evidence of long-range transport occurring (Wu *et al*., 2019; Ma *et al*., 2014; Bohlin-Nizzetto *et al*., 2014, 2015, 2017, 2018, 2019, 2020; Bohlin-Nizzetto & Aas, 2016; Jiang *et al.*, 2021). Table 7 summarises these studies. The values observed at Svalbard between 2013 and 2019 were noted by Bohlin-Nizzetto *et al.* (2020) to be similar to monitoring of rural air in Canada, but significantly lower than measurements in urban and rural sites in China and India (see Table 20 in Appendix 5 for other air monitoring data). Furthermore the levels of "MCCPs" were generally an order of magnitude higher than the concentrations of most of the other studied POPs (including PBDEs such as decaBDE), but 1 to 2

orders of magnitude lower than concentrations of summed PAHs. Jiang *et al.* (2021) similarly found that concentrations of "MCCPs" in the Antarctic exceeded those of polybromodiphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs).

99. Bohlin-Nizzetto *et al.* (2020) note that 42% of "MCCP" samples in 2019 had higher or similar concentrations to SCCPs, which is different to previous years where <10% of "MCCP" values exceeded SCCP concentrations. Jiang *et al.* (2021) also record a significant increasing trend in the ratio of total "MCCPs" to total SCCPs from 2014 to 2018 detected in both aerosol particle and gaseous phases in Antarctica. Data from the Chinese Bohai Sea (Ma *et al.*, 2018) provide further supporting evidence of the potential mechanisms of LRT as the researchers detected "MCCPs" in air samples (both gaseous and particulate) and seawater samples (both dissolved and particulates).

Table 7: Summary of "MCCP" air monitoring data from remote regions

Location	Comment	Units	Concentration	Reference
Shergyla Mountain (Tibetan Plateau)	82 air samples	pg/m^3	52.6 to 687.5	Wu *et al*. (2019)
Zeppelin (Svalbard, Norway)	Weekly air samples*: 2013 2014 2015 2016 2017 2018 2019	pg/m^3	3 – 42 (monthly averages) 23 (annual mean) <3 – 224 (monthly averages) 31 (annual mean) 20 – 595[a] (monthly averages) 130 (annual mean) 10 – 380 (monthly averages) 70 (annual mean) 10 – 423 (monthly averages) 130 (annual mean) 29 – 436 (monthly averages) 120 (annual mean) <44 to 3 900 (monthly averages) 270[b] (annual mean)	Bohlin-Nizzetto *et al.* (2014); Bohlin-Nizzetto *et al.* (2015); Bohlin-Nizzetto & Aas (2016); Bohlin-Nizzetto *et al.* (2017); Bohlin-Nizzetto *et al.* (2018); Bohlin-Nizzetto *et al.* (2019); Bohlin-Nizzetto *et al*. (2020)
King George Island, Antarctica	24 air samples: gaseous phase particulates	pg/m^3	3.0 to 4.5 (average: 3.8) 0.5 to 0.9 (average: 0.7)	Ma *et al*. (2014)

Location	Comment	Units	Concentration	Reference
King George Island, Antarctica	Monthly air samples: 2014 2015 2016 2017 2018	pg/m^3	2.47 (all annual averages) 5.54 6.46 15.1 10.2	Jiang *et al.* (2021)

*Described as “semi-quantitative” measurements due to the high analytical limit of detection.

[a] 60% of the data was below the detection limit.

[b] If two outliers are excluded, the values are: <44 to 720 pg/m^3 (monthly average), or annual mean of 170 pg/m^3.

100. Iozza *et al*. (2009a and 2009b) detected “MCCPs” at concentrations of 0.0052 to 0.095 mg/kg in 8 samples of spruce needles (*Picea alpestris*) collected from the European Alps in October 2004. C_{14} substances with 6 to 8 chlorine atoms per molecule predominated, although 5, 9 and 10 chlorine atom substances (and substances with longer chain lengths) were also detectable at a few percent relative abundance. Wang *et al*. (2016) measured “MCCP” concentrations in Masson Pine (*Pinus massoniana*) needles from Shanghai, China. The measured concentrations were 0.012 to 33.5 mg/kg dw with a geometric mean value of 0.7 mg/kg dw. The details of the analytical method were not available. These findings are likely to reflect atmospheric deposition rather than plant uptake.

101. According to Glüge *et al*. (2018), “MCCP” concentrations in air measured in Asia and Europe are in the same order of magnitude as SCCP concentrations measured at the same locations and points in time. “MCCP” concentrations in air in the Arctic are, however, around one order of magnitude lower than the SCCP concentrations which indicates a slightly lower long-range atmospheric transport potential of “MCCPs” compared with SCCPs (Glüge *et al*., 2018). This observation aligns with monitoring data above, and the OECD model prediction for LRTP for “MCCPs” and SCCPs.

5.4.4. Other environmental monitoring data

102. Appendix 5 provides a summary of environmental monitoring data, based on Environment Agency (2019). CPs with $C_{14\text{-}17}$ chain lengths are not routinely included in environmental monitoring programmes. However, the available European monitoring data generally show widespread occurrence of “MCCPs” in water (at concentrations typically up to a few µg/L), sediment (at concentrations typically up to around 2 mg/kg dw) and biota (typically below 1 mg/kg ww although higher concentrations up to around 80 mg/kg ww have been reported in some studies). “MCCPs” is also found in sewage sludge up to 9 700 mg/kg dw. Levels in dust were reported to be in the low mg/kg range. “MCCPs” was present at concentrations of <0.81 to 14.5 ng/m^3 (mean 3.0 ng/m^3) in air samples from the Hazelrigg field station near Lancaster, UK in 2005.

103. In a comprehensive review, Glüge *et al*. (2018) compared monitoring levels of SCCPs with “MCCPs” in urban, rural and remote locations. For the remote locations, the “MCCP” concentrations from the fish sampled in the Reth *et al*. (2006) study (described in paragraph 67) were noted to be in the upper 50th percentile of the observed concentrations in fish sampled from Canada and Europe (principally Norway). “MCCP” concentrations in the bird eggs were comparable between the Arctic and Norway and ranged between 2.1 and 170 ng/g lipid. It is notable that in the same Arctic study, “MCCP” concentrations in eggs covered a similar concentration range to SCCPs. In the Reth *et al*. (2006) study “MCCP” and SCCP concentrations in the bird muscle and liver tissue were also comparable, with “MCCPs” detected at approximately ten-fold higher concentrations in muscle and liver than in eggs (19 to 1660 ng/g lw). As previously noted, the representivity of the Reth *et al*. (2006) study is limited by the small sample size.

104. In a review article, Vorkamp *et al*. (2019) summarise monitoring of SCCPs and “MCCPs” in environmental compartments and biota in the Arctic. The authors note detection of both substances in sediments, mussels, fish, seabirds and marine mammals. In the case of sediment, “MCCPs” was below the limit of detection (0.1 to 0.3 ng/g dw) in all but one sample (4.8 ng/g dw).

105. “MCCPs” has been detected in the plasma of Ringed Seals (*Pusa hispida*) and Polar Bears (*Ursus maritimus*) from the Arctic with quoted concentrations of 74 and 600 µg/kg lipid. These were in the same order of magnitude as SCCPs in the same samples, but at marginally lower values (NILU, 2013).

5.4.5. Long range transport synthesis

106. The predicted atmospheric half-life for four relevant C_{14} and C_{17} constituents are between 37 and 62 hours. It is difficult to validate these estimated values due to the lack of experimental data, and so they are considered uncertain. The two modelled C_{14} constituents are at or above the 48 hour threshold in Annex D. The two modelled C_{17} constituents are below 48 hours. The C_{17} constituents are less relevant for (gaseous) atmospheric photodegradation as a greater fraction will be adsorbed to aerosols. More highly chlorinated constituents will be more photolytically stable and more adsorptive.

107. Using the OECD Screening Tool, the LRTP for these constituents are comparable to, but slightly below those for SCCPs, which is a POP. It also falls within the range of other listed POPs. CPs with $C_{14\text{-}17}$ chain lengths have low volatility and are expected to adsorb strongly to particulates. Given the relatively high gaseous fraction predicted for the C_{14} constituents in the OECD Screening Tool, it is not clear how well the adsorption of the constituents is actually modelled. Several lines of evidence from other models and experimental data suggest that the fraction adsorbed to aerosols could be higher. The atmospheric transport of airborne particulates provides a potential route for long range transport, and this is supported by the detection of “MCCPs” at low levels in air samples taken in remote locations. These include 5 years’ monitoring in the Arctic and Antarctica, and recent sampling at the Tibetan Plateau. “MCCPs” monitoring at Svalbard suggests levels in air are increasing at this remote location. The ratio of “MCCPs” to SCCPs is also

observed to be increasing in Antarctic air. The levels of “MCCPs” observed in both these remote locations was noted to be higher than some listed POPs such as PBDEs.

108. The modelled comparability to SCCPs is further supported by the detection of “MCCPs” in environmental samples from remote regions, including in top predators. In some instances, the levels of “MCCPs” appear to be similar to SCCPs. There is also environmental monitoring data showing the detection of “MCCPs” in different matrices at locations in the following countries: Australia, Belgium, Canada, China, Czech Republic, Denmark, France, Germany, India, Ireland, Japan, Norway, Pakistan, Sweden, Switzerland, UK and USA, as well as various marine locations such as the Baltic Sea, Irish Sea, North Sea in Europe and Chinese Bohai Sea (refer to Appendix 5).

109. Overall, the Annex D criteria for Long Range Transport 1d(i), (ii) and (iii) are considered to be met. Limited biota monitoring data indicate detection of “MCCPs” in remote areas, with similar concentrations to SCCPs suggested in some studies. Air sampling data are also limited to specific locations, but the available information confirms the potential for transport via this medium. The predicted atmospheric half-life of the modelled constituents is around 2 days with values above and below the threshold. It remains unclear how accurate these predictions are, and to what degree the gaseous transport of CPs with C_{14-17} chain lengths is relevant compared to adsorption to particles. Other monitoring data indicate that “MCCPs” are widely detected in the environment.

110. In conclusion, the limited data indicate that there is both a pathway and delivery of CPs with C_{14-17} chain lengths to remote locations. The concern is that the characteristics of these constituents, while slightly less efficiently transported over long distances than SCCPs, appear to be similar to that POP.

5.5. Adverse effects

5.5.1. Ecotoxicity

111. Since CPs with C_{14-17} chain lengths contain thousands of constituents, the reported toxicity end points effectively reflect an average of the contributions that individual constituents make. The influence of varying degrees of chlorination and chain length on toxicity is not known. It is therefore assumed that if toxicity is demonstrated for one type of product, it will be applicable for all, although this is an area of uncertainty.

112. The key data for the proposal are two aquatic toxicity studies performed with *Daphnia magna* using a C_{14-17} chlorinated n-alkane, 52% Cl wt. The first is an acute test performed according to OECD TG 202 and GLP that is considered to be reliable without restriction. This determined a 48-h EC_{50} value of 5.9 µg/L, based on (arithmetic) mean measured concentrations (Thompson *et al*., 1996). The second is a long-term test performed according to OECD TG 202 (later superseded by OECD TG 211) and GLP that is also considered to be reliable without restriction

(Thompson *et al*., 1997a). The study met the validity criteria of the later test guideline as well as OECD TG 202. Based on the chemical analysis, results were calculated as time-weighted mean values, with the 21-day NOEC for reproduction and length being 8.7 µg/L. The lower EC_{50} value might be explained by the absence of food compared to the longer test (leading to greater availability of the substance and differences in elimination efficiency of the organisms).

113. The available acute and chronic data for fish and algae cited in EA (2019) and EC (2005) suggest that these taxa are less sensitive to "MCCPs" than *D. magna*. Long-term fish data are limited, but a GLP 60-d study using Rainbow Trout (*O. mykiss*) exposed to $C_{14\text{-}17}$ CP, 52% Cl wt. found no effects on mortality, growth or behaviour at 4.5 mg/L (Madeley *et al.*, 1983). In a 72-h study performed with a $C_{14\text{-}17}$ CP, 52% Cl wt. according to OECD TG 201 and GLP (Thompson *et al*., 1997b), little or no toxic effect on the growth of the green alga *Selenastrum capricornutum* occurred at concentrations up to 3.2 mg/L.

114. A further long-term invertebrate toxicity study was summarised in EC (2005). This reported a 60-d NOEC of 0.22 mg/L for a $C_{14\text{-}17}$, 52% Cl wt. substance with Blue Mussel *Mytilus edulis* (Madeley and Thompson, 1983).

115. Reflecting the toxicity to *Daphnia magna*, "MCCPs" has a harmonised EU environmental classification of Aquatic Acute 1, Aquatic Chronic 1 (H400, H410) in accordance with the UN Globally Harmonised System. More recent self-classification by the lead EU REACH Registrants includes an M-factor for acute and chronic aquatic hazards of 100 and 10, respectively. Given the stringent environmental classification, no further toxicity studies for pelagic aquatic organisms are summarised in this proposal.

116. Three reliable prolonged sediment toxicity studies for "MCCPs" conducted in accordance with GLP using three taxa (*Hyalella azteca, Lumbriculus variegatus* and *Chironomus riparius*) are summarised in EC (2005 & 2007). These used sediment spiked with a $C_{14\text{-}17}$, 52% Cl wt. substance. The lowest NOEC was 130 mg/kg dw (~ 50 mg/kg ww), obtained in the study with *Lumbriculus variegatus* and also *Hyalella azteca.* EC (2005 & 2007) also reports three reliable long-term terrestrial toxicity studies conducted in accordance with GLP with the same chemical using earthworms (OECD TG 222), terrestrial plants (OECD TG 208) and soil microorganisms (OECD TG 216). Earthworms were the most sensitive species, with a 56-d NOEC of 280 mg/kg dw.

5.5.2. Human health toxicity

117. The EU human health risk assessment report (HSE, 2008) provides a summary of the available laboratory mammalian testing, which used one commercial product type (a $C_{14\text{-}17}$, 52% Cl wt. substance) for the majority of regulatory studies. A more recent review performed by the European Food Safety Authority (EFSA, 2020) relies on the same key hazard data.

118. The target organs for repeated oral dose toxicity are liver, thyroid and kidney. EFSA (2020) identified changes in kidney weights as the critical effect of "MCCPs" of relevance to humans. Eight relevant repeated dose toxicity studies were

reviewed in HSE (2008). The assessment determined the lowest NOAEL of toxicological significance to be 23 mg/kg bw/day from a 90-d study with F344 rats *Rattus norvegicus* (CXR Biosciences Ltd, 2005b), based on increased relative kidney weights (HSE, 2008). A second 90-day study also using F344 rats *Rattus norvegicus* recorded a NOAEL of 10 mg/kg bw/day for the same endpoint (IRDC, 1984). EFSA (2020) has derived a $BMDL_{10}$[12] of 36 mg/kg bw/day from this second study (the BMDU/BMDL ratio of 6 indicates some uncertainty in the value). The $BMDL_{10}$ for CXR Biosciences Ltd (2005b) was 68 mg/kg bw/day (BMDU/BMDL ratio 2.7).

119. No carcinogenicity studies have been conducted. "MCCPs" is generally unreactive and not mutagenic. The carcinogenic potential of "MCCPs" is expected to be similar – at least in qualitative terms – to that of SCCPs, although direct read across is not appropriate. SCCPs induce liver and thyroid adenomas and carcinomas and kidney tubular cell adenomas and carcinomas in animal studies. The liver and thyroid tumours are considered to be of little or no relevance to human health. It cannot be completely ruled out that the kidney toxicity observed for "MCCPs" might lead to kidney cancer in rats through a non-genotoxic mode of action. However, "MCCPs" is not classified for this end point in Europe under Regulation (EC) No. 1272/2008.

120. "MCCPs" has no apparent effect upon fertility in rats up to approximately 400 mg/kg/day in the diet. No adverse developmental effects occurred during gestation in rats or rabbits in two conventional developmental studies using maternal doses up to 5 000 and 100 mg/kg/day, respectively. In contrast, exposure of Wistar rats *R. norvegicus* to $C_{14\text{-}17}$ CP, 52% Cl wt. at a maternal dietary dose of 74 mg/kg/day (1 000 ppm) up to approximately 400 mg/kg/day (6 250 ppm) produced internal haemorrhaging and deaths in the pups (IRDC, 1985). Follow-up studies with Sprague Dawley rats (CXR Biosciences Ltd, 2003, 2004 & 2006) demonstrated that "MCCPs" can perturb blood clotting. In adult females that had been treated for 7 to 8 weeks including pregnancy and lactation, decreased levels of vitamin K and of the clotting factors VII and X were found, and 5 out of 32 dams showed signs of haemorrhaging during parturition. However, these decreases did not affect their prothrombin times, indicating that the functional reserve in the majority of these adult animals was sufficient. The foetus *in utero* apparently receives sufficient vitamin K via the placenta, but after birth becomes severely deficient in vitamin K and related clotting factors and relies on the mothers' milk to receive them. Exposure to "MCCPs" in the milk may also further reduce their vitamin K levels. This in turn leads to a severe vitamin K deficiency in the neonates and consequently to haemorrhaging. This is the basis for the harmonised EU classification for effects via lactation (H362 – May cause harm to breast-fed children) according to Regulation (EC) No. 1272/2008.

121. From the studies available, an overall NOAEL of 47 mg/kg/day (600 ppm) as a maternal dose was identified for these effects mediated via lactation (EC, 2005).

[12] Benchmark Dose Level associated with a 10% response adjusted for background.

However, it should be noted that the effects (11% reduction in pup survival and related haemorrhaging) observed at the LOAEL (74 mg/kg/day; 1 000 ppm) were not statistically significant. Haemorrhaging was also seen in one study at the time of parturition in 16% of dams given 538 mg/kg/day (6 250 ppm), but not up to 100 mg/kg/day (1 200 ppm) in other studies. The NOAEL of 100 mg/kg/day (1 200 ppm) was therefore selected for the risk characterisation of haemorrhaging effects potentially occurring in pregnant women at the time of parturition. EFSA (2020) estimated the $BMDL_5$ values of 48.5 mg/kg bw/day (BMDU/BMDL ratio of 1.3) for the combined incidence of subcutaneous haematoma/haemorrhage in rats and 53 mg/kg bw/day (BMDU/BMDL ratio of 1.8) for rat pup deaths (EFSA, 2020).

122. "MCCPs" does not meet the criteria for classification as carcinogenic (category 1A or 1B), germ cell mutagenic (category 1A or 1B), toxic for reproduction (category 1A, 1B, or 2) or specific target organ toxicity after repeated exposure (STOT RE category 1 or 2) in Europe according to Regulation (EC) No. 1272/2008.

123. An EU statement code EUH066 (Repeated exposure may cause skin dryness or cracking) is applied for "MCCPs". The same statement is applied in Australia (code AUH066) (Pers. Comm., 2021).

5.5.3. Adverse effects synthesis

124. A $C_{14\text{-}17}$ chlorinated n-alkane, 52% Cl wt. has a 48-h EC_{50} of 0.0059 mg/L for *Daphnia magna.* The 21-day NOEC for the same species and substance is 0.0087 mg/L. These two results, from reliable laboratory studies performed to recognised OECD test guidelines and to GLP, indicate that constituents of CPs with $C_{14\text{-}17}$ chain lengths are very toxic to aquatic invertebrates in the environment.

125. The concern for adverse effects is supported by the internal haemorrhaging and death observed in rodent offspring in the mammalian reproduction study resulting in a harmonised EU classification for "MCCPs" as H362 (May cause harm to breast-fed children). Potential adverse effects could therefore occur in mammalian wildlife.

126. Overall, the Annex D criteria 1e(i) for adverse effects are considered to be met.

6. Manufacture, supply and environmental emission

6.1. Uses and supply

127. Within the EU, there are 10 active REACH Registrants of "MCCPs" listed on the ECHA dissemination portal (ECHA 2021b). The registered tonnage lies in the band 10 000 – 100 000 tonnes per year. Based on the EU REACH registration information, the substance has a number of uses, such as:

- a secondary plasticizer in PVC, adhesives, sealants, paints and coatings;
- a flame retardant in PVC and rubber compounds, adhesives, sealants, paints and coatings, and textiles;
- an extreme pressure lubricant and anti-adhesive for metal working fluids;

- a waterproofing agent for paints, coatings and textiles; and
- a carrier solvent for colour formers in paper manufacture.

128. Former uses reported in EC (2005) were for leather fat liquors and carbonless copy paper. These are no longer included in the latest REACH registration dossiers. However, it is possible that these uses continue elsewhere.

129. Most “MCCPs” used in the EU is manufactured within the EU with only a small proportion (<10%) imported from outside the bloc. “MCCPs” may also be imported into the EU in finished or semi-finished articles (e.g. textiles or electrical items). The total mass of “MCCPs” entering the EU in imported articles is unknown, so it is not possible to gain a full insight into stocks and mass flows. KEMI (2018) estimated that the EU imported approximately 2 100 tonnes of “MCCPs” in electrical cables in 2014. There are 532 notifiers of “MCCPs” in ECHA’s Classification & Labelling Inventory (ECHA 2020), which suggests a large number of downstream users in Europe (there is no lower supply threshold for the inventory, so some notifications may be for low volumes, but verification is not possible).

130. Outside Europe, Glüge *et al*. (2018) cite the following production volumes of “MCCPs”: North America (17 800 tonnes in 1998), Russia (21 000 tonnes in 2007 and 27 000 tonnes in 2011), Thailand (20 000 tonnes in 1994) and China (estimated to be 600 000 tonnes in 2013, extrapolated from CP-52 production). Some of these values are more than 20 years old, and so current supply volumes may have changed. Glüge *et al*. (2018) suggest that Chinese production may have continued to increase after 2013, based on the supply trend prior to that year. In Australia, the total annual introduction volumes in 2002 and 2006 were between 1 000 and 9 999 tonnes (NICNAS, 2020), which are thought to mainly reflect Australian manufacture (Pers Comm., 2021). Manufacture in India, possibly at a significant supply volume, is also suggested (Lassen *et al*., 2014), but information specific to CPs with $C_{14\text{-}17}$ chain lengths is not available.

131. Based on the available data, current global production of CPs with $C_{14\text{-}17}$ chain lengths could be in the region of 750 000 tonnes per year.

6.2. Emissions estimates

132. As part of the Risk Management Options Analysis for “MCCPs” in the EU, the release estimates for the different lifecycle stages were estimated based on information[13] in the REACH Registrants’ Chemical Safety Reports (UK, 2019). The values are provided in Table 8 and Table 9. A total of 305 tonnes per year is estimated to be emitted to the environment. The total estimated release to surface water in Table 9 reflects the removal of “MCCPs” from aqueous waste streams by wastewater treatment plants. This diverts approximately 149 tonnes per year of “MCCPs” to sludges, which may be landfilled, used in agriculture or incinerated.

[13] Tonnage relevant for the lifecycle and quoted emission factor.

Based on this information, if the proportion of "MCCPs" released per year in the EU is applied to the estimated global supply tonnage[14], this suggests between 2 800 and 28 000 tonnes per year is being released to the environment at a global scale. Clearly the global tonnage is an approximation, and this calculation assumes that the EU use pattern and emission controls are similar across the world (which is unlikely to be the case).

Table 8: Estimated total releases of "MCCPs" to the EU environment by use (from all lifecycle stages)

Use	Total releases per year (tonnes)
"MCCPs" manufacture	0
PVC and rubber (formulation, conversion, service life)	41
Adhesives/sealants (formulation, use, service life)	126
Metalworking fluids (formulation and use)	100
Textiles (formulation and service life)	13
Paints/coatings (formulation, use, service life)	10
Paper manufacturing/recycling	15
TOTAL	**305**

Table 9: Estimated total releases of "MCCPs" to the EU environment from all lifecycle stages

Release route	Total releases per year (tonnes)
Water	4
Air	91
Soil	61
Sewage sludge*	149

* which may be used in agriculture, landfilled or incinerated

7. Conclusion and need for action

133. For CPs with C_{14-17} chain lengths, there are reliable laboratory data clearly indicating that constituents with a C_{14} chain length and chlorination levels around 45-50% Cl wt. *meet all* of the Annex D screening criteria for persistence, bioaccumulation and adverse effects. Data for C_{15}, C_{16} and C_{17} constituents suggest that these also meet the persistence and toxicity screening criteria. These longer chains may meet the bioaccumulation criteria, but fully reliable data to confirm this are not available. Long range transport potential is considered to be shown for all chain lengths.

[14] 305 tonnes/year released from the range of 10 000 to 100 000 tonnes supplied in the EU applied to the estimated global use volume of 750 000 tonnes/year.

134. The persistence information indicates that the concern is for all constituents with chlorination levels at or exceeding 45% chlorine by weight.

135. The C_{14} constituents are a major congener group in commercial CP products currently being supplied. This indicates that CPs with C_{14-17} chain lengths will contain a significant fraction of constituents that meet the Annex D screening criteria. Of the remaining fraction, a significant proportion meets three out of the four criteria, with weaker evidence for the bioaccumulation endpoint. Given the potential bioaccumulation concern from the available data for these longer chains together with the evidence for the other criteria, it is proposed to include all four carbon chain lengths in the listing.

136. It is noted that laboratory bioaccumulation data of limited reliability are available for a C_{18} constituent. The focus of this proposal is the C_{14-17} chain lengths, and this reflects the data available for the other endpoints and generally the monitoring data. Therefore chain lengths longer than C_{17} are not included within the proposal. As noted in paragraph 13 an update of a national assessment of “LCCPs” is currently in progress by the UK, which will assess C_{18} chain lengths (and above).

137. As a result of its PBT properties, “MCCPs” is of regulatory concern in the UK, EU, Switzerland, Australia and Canada. The different applications and ongoing use of CPs with C_{14-17} chain lengths globally is estimated to result in around 2 800 to 28 000 tonnes being potentially emitted to the environment each year. Due to the hazard concerns for the substance, and the estimated level of environmental emissions, global action is required to manage the risks from CPs with C_{14-17} chain lengths.

138. In conclusion, it is proposed to list carbon chain lengths in the range C_{14-17} and chlorination levels ≥45% chlorine by weight in the Convention.

Appendix 1: Abbreviations

AOPWIN	Atmospheric Oxidation Program
APCI-QToF-HRMS	Atmospheric-Pressure Chemical Ionization Quantitative Time of Flight High Resolution Mass Spectrometry
BAF	Bioaccumulation Factor
BCF	Bioconcentration Factor
BCFss	Steady State BCF
BMDL	Benchmark dose (lower confidence limit)
BMDU	Benchmark dose (upper confidence limit)
BMF	Biomagnification Factor
BMF_{KgL}	Growth-corrected and lipid-normalised kinetic biomagnification factor
BSAF	Biota-sediment accumulation factor
bw	Bodyweight
Ca.	Circa (“approximately”)
CAS number	Chemical Abstracts Service number
Cl wt.	Chlorine content by weight
CLP	Classification, Labelling and Packaging
CPs	Chlorinated paraffins
CTD	Characteristic Travel Distance
Cx	Carbon chain with x Carbon atoms
dw	Dry weight
EC_{50}	Half maximal effective concentration
EC number	European Community Number
EC (reg)	European Union council (regulation)
ECHA	European Chemicals Agency
EFSA	European Food Safety Authority
EU	European Union
GC-ECNI-LRMS	Gas Chromatography Electron Capture Negative Ionisation Low Resolution Mass Spectrometry
GCxGC-ECD	Two Dimensional Gas Chromatography with Electron Capture Detector
GHS	Globally Harmonised System
GLP	Good Laboratory Practise
HCB	Hexachlorobenzene
HPLC	High Performance Liquid Chromatography

HRMS	High Resolution Mass Spectrometry
HSE	Health & Safety Executive
K_{OC}	Organic carbon-water partition coefficient
K_{OW}	Octanol/water partition coefficient
LCCP(s)	Long chain chlorinated paraffin(s)
LOD	Limit of detection
LOQ	Limit of Quantification
LRT	Long range transport
LRTP	Long range transport potential
lw	Lipid weight
MCCP(s)	Medium chain chlorinated paraffin(s)
M-factors	Multiplication Factors
NICNAS	National Industrial Chemicals Notification and Assessment Scheme
NOAEL	No Observed Adverse Effect Level
NOEC	No Observed Effect Concentration
OECD	Organisation for Economic Co-operation and Development
OH-Radical	Hydroxyl radical
PBDEs	Polybromodiphenyl ethers
PBPK	Physiologically-based pharmacokinetic modelling
P_{OV}	Overall persistence
PBT	Persistent, Bioaccumulative and Toxic
PCBs	Polychlorinated biphenyls
POP	Persistent Organic Pollutant
PVC	Poly Vinyl Chloride
REACH	Registration, Evaluation and Authorisation of Chemicals
RMOA	Regulatory Management Option Analysis
RP-HPTLC	reversed-phase high performance thin layer chromatography
RSD	Relative Standard Deviation
SCCP(s)	Short chain chlorinated paraffin(s)
SMILES	Simplified Molecular Input Line Entry System
SVHC	Substance of very high concern
TE	Transfer Efficiency
TG	Test Guideline
ThOD	Theoretical Oxygen Demand

TMF	Trophic Magnification Factor
TOC	total organic carbon
UN	United Nations
UNEP	United Nations Environment Programme
UVCB	Unknown Variable Concentration or Biological
WHO	World Health Organisation
ww	Wet weight

Appendix 2: List of references (including for data in the appendices)

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Appendix 3: Further information on substance identity

Table 10: Constituents present in amounts <1% by weight in "MCCPs" on the EU market

Constituent	Typical concentration (w/w)	Concentration range	Remarks
Chlorinated alkanes with carbon chain lengths $<C_{14}$	<1%	Not specified	Based on information in EC (2005) and information in the REACH registration dossiers, assuming that the alkanes in the feedstock are chlorinated during manufacture of "MCCPs".
Chlorinated aromatics	<100 mg/kg	Not specified	Based on information in EC (2005) assuming that aromatics and isoparaffins in the feedstock are chlorinated during manufacture of "MCCPs".
Chlorinated isoparaffins	<1 - 2%	Not specified	

All constituents in commercial CPs are likely to be related to those present in the n-paraffin feedstock, in which the major non-paraffinic constituent is a small proportion of aromatics and isoparaffins. EU producers of "MCCPs" represented by EuroChlor have, since 1991, used paraffin feedstocks in the production process with a $C_{<14}$ content of <1% by weight and reported that the actual levels are often much lower than this (EC, 2005).

Various stabilisers can be added to commercial CPs at <1% by weight to improve thermal or light stability (EC, 2005). These include epoxidised soya oil and glycidyl ethers.

The details of substance identity for short chain chlorinated paraffins (SCCPs) and long chain chlorinated paraffins (LCCPs) from the EU REACH registrations can be found in Table 11 (ECHA 2021c and 2021d).

Table 11: Substance identity of relevant structural analogues

EC name	Alkanes, C_{10-13}, chloro	Paraffin waxes and hydrocarbon waxes, chloro
EC number	287-476-5	264-150-0
CAS number	85535-84-8	63449-39-8
Molecular formula	$C_xH_{(2x - y+2)}Cl_y$, where x = 10 - 13 and y = 1 - 13	$C_xH_{(2x - y+2)}Cl_y$, where x = 18 - 30 and y = 1 - 30
Molecular weight range	320 - 500 g/mole (approximately)	420 - 1 355 g/mole (approximately)

Synonyms	Short-chain chlorinated paraffins (SCCPs); alkanes, C_{10-13}, chloro; chlorinated paraffins, C_{10-13} (used in Annex VI of the CLP Regulation)	Long-chain chlorinated paraffins (LCCPs); alkanes, C_{18-30}, chloro; chlorinated paraffins, C_{18-30}

Around forty CAS numbers have been used to describe the whole CP family at one time or another. Some of these are now historical, and others may be in use for the sole purpose of compliance with national or regional chemical inventories. A list has been provided by representatives of the EU REACH LCCPs Consortium (Personal Communication, 2019). This is shown in Table 12, and is not necessarily exhaustive. Those CAS numbers that may be associated with C_{14-17} chain lengths are highlighted in bold.

Table 12: CAS numbers associated with CPs

CAS Number	CAS name	Note	Regulatory Regions
915-934-2	**Reaction mass of alkanes, C_{14-17}, chloro and paraffin waxes and hydrocarbon waxes, chloro**	-	-
61788-76-9[a]	**Alkanes, chloro; alkanes, chlorinated**	c	[1a], [1c], [2], [3], [4], [5a], [6a], [7], [8], [10], [11], [12]
63449-39-8[b]	Paraffin waxes and hydrocarbon waxes, chloro	b	[1a], [1b], [1c], [2], [3], [4], [5a], [6a], [6b], [7], [8], [9], [10], [11], [12]
68920-70-7	**Alkanes, C_{6-18}, chloro**	a	[1a], [1b], [1c], [2], [3], [4], [5a], [6a], [7], [8], [12]
71011-12-6	Alkanes, C_{12-13}, chloro	d	[2], [3], [5a]
84082-38-2	**Alkanes, C_{10-21}, chloro**	a	[1a], [1c], [3], [4], [5a], [7], [8], [9], [12]
84776-06-7	**Alkanes, C_{10-32}, chloro**	a	[1a], [1c], [3], [4], [5a], [7], [8], [9], [12]
84776-07-8	**Alkanes, C_{16-27}, chloro**	a	[1a]
85049-26-9	**Alkanes, C_{16-35}, chloro**	a	[1a], [4]
85422-92-0	**Paraffin oils and hydrocarbon oils, chloro**	c	[1a], [9]
85535-84-8	Alkanes, C_{10-13}, chloro	d	[1a], [1b][c], [1c], [3], [4], [5a], [6a], [7], [8], [12]
85535-85-9	**Alkanes, C_{14-17}, chloro**	b	[1a], [1b], [1c], [2], [3], [4], [5a], [5b], [7], [8], [9], [10], [12]

CAS Number	CAS name	Note	Regulatory Regions
85535-86-0	Alkanes, C_{18-28}, chloro	a	[1a], [3], [4], [6a], [7], [9]
85536-22-7	**Alkanes, C_{12-14}, chloro**	a	[1a], [3], [4], [6a], [9], [12]
85681-73-8	**Alkanes, C_{10-14}, chloro**	a	[1a], [5a]
97553-43-0	**Paraffins (petroleum), normal $C_{>10}$, chloro**	a	[1a], [5a]
97659-46-6	**Alkanes, C_{10-26}, chloro**	a	[1a], [9]
106232-85-3	Alkanes, C_{18-20}, chloro	b	[2], [3], [4], [5a], [9], [10], [12]
106232-86-4	Alkanes, C_{22-40}, chloro	a	[1a], [4], [9]
108171-26-2	Alkanes, C_{10-12}, chloro	a	[1a], [7], [8], [9]
108171-27-3	Alkanes, C_{22-26}, chloro	a	[1a], [5a] [12]
288260-42-4	Alkanes, C_{22-30}, chloro	b	[2], [7]
198840-65-2	**Tetradecane, chloro derivatives**	b	[2]
1372804-76-6	**Alkanes, C_{14-16}, chloro**	b	[2]
2097144-48-2	Octadecane, chloro derivatives	b	[2]
2097144-45-9	Alkanes, C_{20-24}, chloro	b	[2]
2097144-43-7	Alkanes, C_{20-28}, chloro	b	[2]
2097144-44-8	**Slackwax (petroleum), chloro**	b	[2]
1417900-96-9	Alkanes, C_{21-34}-branched and linear, chloro	b	[2]
1401974-24-0	Alkanes, C_{22-30}-branched and linear, chloro	b	[2]
1402738-52-6	Alkanes, C_{24-28}, chloro	b	[2]
2097144-46-0	Hexacosane, chloro derivatives	b	[2]
2097144-47-1	Octacosane, chloro derivatives	b	[2]

[a]CAS 61788-76-9 replaces 11104-09-9, 12633-77-1, 51059-93-9, 53572-39-7 and 69430-53-1: [b]CAS 63449-39-8 replaces 8029-39-8, 11098-33-2, 37187-40-9, 39279-65-7, 39406-09-2, 39444-36-5, 50646-90-7, 51990-12-6, 52276-52-5, 52555-47-2, 52622-66-9, 52677-73-3, 52677-74-4, 52677-75-5, 53028-59-4, 53028-60-7, 53200-

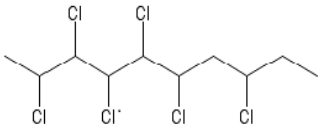
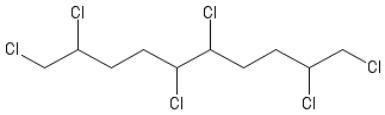
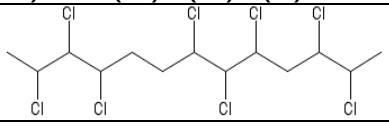
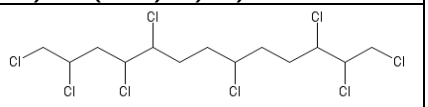
35-4, 54577-71-8, 55353-50-9, 56509-64-9, 56730-95-1, 58516-52-2, 60202-64-4, 66746-35-8 and 108688-63-7: [c]withdrawn

Note: a - Listed on at least one national inventory; b - Registered under legislation requiring dossier submission in 21st century; c - Broad scope with no carbon number definition (not favoured by some authorities); d - Subject to ban or restriction, substance of very high concern (EU) or Toxic Release Inventory requirement (USA).

Regulatory Regions: [1a] EU REACH pre-registered; [1b] EU REACH registered; [1c] EU CLP Inventory [2] USA TSCA (active list); [3] Canada DSL; [4] Australia (AICS); [5a] Korean Gazette No.; [5b] Korean REACH registered; [6a] Japan ENCS; [6b] Japan examined; [7] Philippines; [8] New Zealand; [9] Taiwan; [10] Turkey; [11] Switzerland (other CAS numbers in the table are also registered in Switzerland beyond the two indicated); [12] China.

Appendix 4: Further information for LRT modelling

Table 13: Input (predicted) values for two C_{10-13} constituents (SCCPs) used to predict their LRTP

Parameters	**C_{10} constituent (61% Cl wt.)**	
OECD LRTP ID	**SCCP-1 (non-terminal chlorine)**	**SCCP-2 (terminal chlorine)**
SMILES	ClC(CC(Cl)CC)C(Cl)C(Cl)C(Cl)C(C)Cl	C(CC(C(CCC(CCl)Cl)Cl)Cl)C(CCl)Cl
Structure		
Molecular mass (g/mol)	348.9	348.9
Molecular formula	$C_{10}H_{16}Cl_6$	$C_{10}H_{16}Cl_6$
Log K_{AW}	-1.133	-1.133
Log K_{OW}	6.34	6.48
Log K_{OA}	7.47	7.61
OH rate constant at 25 °C (cm^3/molecule-sec)	2.67 x 10^{-12}	3.22 x 10^{-12}
Half-life in air (h)*	144.3	119.7
Half-life in water (h)	4 320	4 320
Half-life in soil (h)	8 640	8 640
Parameters	**C_{13} constituent (61% Cl wt.)**	
OECD LRTP ID	**SCCP-3 (non-terminal chlorine)**	**SCCP-4 (terminal chlorine)**
SMILES	CC(Cl)C(Cl)CC(Cl)C(Cl)C(Cl)CCC(Cl)C(Cl)C(C)Cl	C(Cl)(C(Cl)CCC(Cl)CCC(C(Cl)CC(CCl)Cl)Cl)CCl
Structure		
Molecular mass (g/mol)	459.9	459.9
Molecular formula	$C_{13}H_{20}Cl_8$	$C_{13}H_{20}Cl_8$
Log K_{AW}	-1.67	-1.67
Log K_{OW}	8.17	8.32
Log K_{OA}	9.84	9.99
OH rate constant at 25 °C (cm^3/molecule-sec)	3.07 x 10^{-12}	4.55 x 10^{-11}
Half-life in air (h)*	125.3	84.7
Half-life in water (h)	4 320	4 320
Half-life in soil (h)	8 640	8 640

Note: * Derived using a global annual average hydroxyl radical concentration of 5 x 10^5 molecule/cm^3 in REACH Guidance R.16 (ECHA, 2016)

As a test of sensitivity and the use of predicted physico-chemical values, experimental values for log K_{OW} (6.58) and a log K_{AW} of -2.0 were used as input values for the C_{14} constituent (see Table 5). The log K_{AW} of -2.0 is calculated from experimental values for vapour pressure (2.7×10^{-4} Pa at 20 °C) and water solubility (6.1 µg/L at 20 °C). Using these values but with the same degradation half-lives predicts a P_{OV} of 503 days, a CTD of 1 258 km and a TE of 0.18% for MCCP-1. For MCCP-2, a P_{OV} of 503 days, a CTD of 985 km and a TE of 0.11% was predicted. Therefore overall, the use of the measured data makes little difference to the modelled outcome using the EPI Suite™ input predictions. The predicted CTD and TE are heavily influenced by partitioning to the particle phase. A lower input value of log K_{AW} results in an increase in the log K_{OA} and in the predicted CTD and TE as the predicted proportion of CPs with C_{14-17} chain lengths in the particle phase increases.

Environment Canada (2008) reported atmospheric half-lives for vapour phase "MCCPs" ranging from 2.7 to 7.1 days (64.8 to 170.4 hours). The sensitivity of the OECD tool to this range of half-lives is shown in Table 14.

Table 14: Sensitivity of the LRTP predictions to different atmospheric half-lives from Environment Canada (2008)

Predictions	**C_{14} constituent (52.6% Cl wt.)[a]**			
	MCCP-1 (non-terminal chlorine)		**MCCP-2 (terminal chlorine)**	
Atmospheric half-life (h)	**64.8**	**170.4**	**64.8**	**170.4**
CTD (km)	1 344	3 479	1 344	3 477
TE (%)	0.052	0.35	0.056	0.37
P_{OV} (days)	512	513	512	513
Predictions	**C_{17} constituent (51.6% Cl wt.)[a]**			
	MCCP-3 (non-terminal chlorine)		**MCCP-4 (terminal chlorine)**	
Atmospheric half-life (h)	**64.8**	**170.4**	**64.8**	**170.4**
CTD (km)	1 575	3 275	1 625	3 243
TE (%)	1.13	4.88	1.4	5.57
P_{OV} (days)	519	519	519	519

Note: a – For explanations about the actual structures selected, see Section 5.4.2.

Glüge *et al*. (2013) investigated variability of predicted values for physico-chemical properties of CPs. They calculated log K_{OW} values for 29 "MCCPs" congener groups using COSMOtherm and EPI Suite™, and compared the results to experimental data from the literature. They reported that good or very good agreement was obtained between calculated and measured data for COSMOtherm but EPI Suite™ showed the largest discrepancies for all properties and therefore is potentially less reliable. Glüge (Pers. Comm., 2021) predicted log K_{AW} and log K_{OW} values using COSMOtherm for two of the MCCP congeners. These have been used to investigate the sensitivity of the OECD LRTP results. K_{AW} and K_{OW} input parameters were changed whilst retaining the other values as Table 5. The results are presented in Table 15 below. There is a large increase in the TE and a more modest increase in the CTD for the two constituents when using COSMOtherm.

Table 15: Sensitivity of the LRTP predictions to using predicted Log K_{AW} and Log K_{OW} from COSMOtherm

Parameter	C_{14} constituent (52.6% Cl wt.)	C_{17} constituent (51.6% Cl wt.)
	MCCP-1 (non-terminal chlorine)	MCCP-3 (non-terminal chlorine)
Log K_{AW}	-4.93	-5.73
Log K_{OW}	6.4	7.9
Log K_{OA}	11.33	13.66
Predictions		
Characteristic Travel Distance (km)	1 601	2 826
Transfer Efficiency (%)	3.94	12.4
P_{OV} (days)	518	518

ECHA (2021) used the ACD Percepta program to predict log K_{OW} for "MCCPs" congener groups including structural isomers. For $C_{14}H_{24}Cl_6$ and $C_{17}H_{29}Cl_7$, the predicted log K_{OW} ranged from 6.36 to 7.01 and 7.33 to 8.67. These are broadly comparable to the predicted values in Table 15 and therefore a comparable effect on the predicted LRTP results is expected.

Physical removal of a chemical substance from the atmosphere can occur by wet and/or dry deposition of a gaseous or particulate substance. The distribution of the chemical between gas and particulate phases affects deposition rates and chemical reactivity that alters the long-range transport and distribution properties of a chemical (Boethling *et al*., 2004).

The OECD Tool estimates the fraction of substance sorbed to atmospheric particulates which is used to estimate the atmospheric transport potential. The AEROWIN v1.0 Program estimates the fraction of substance sorbed to atmospheric particulates, which is also known as the parameter phi, by three methods:

- Junge-Pankow Adsorption Model;
- Mackay Adsorption Model; and
- Octanol-Air Partition Coefficient Model.

Estimates for the predicted fraction of "MCCPs" and SCCPs sorbed to atmospheric particulates is presented in Table 16 and

Figure **4**. For the majority of CP congeners presented in Table 16 and

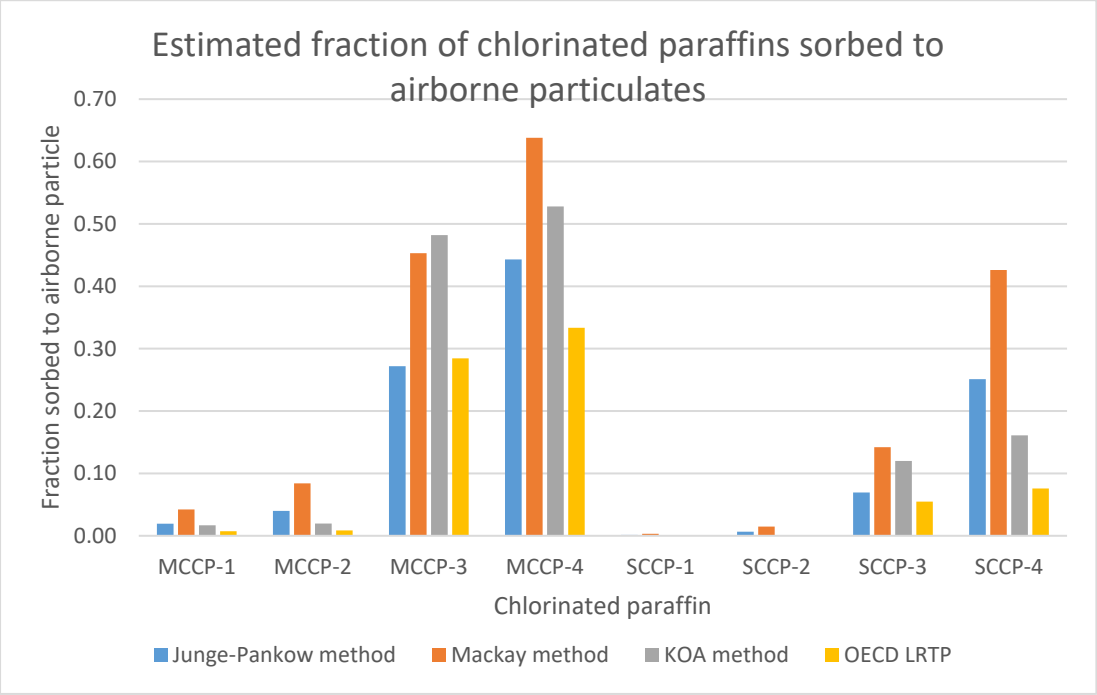
Figure **4**, the fraction sorbed to particulates predicted by the OECD Tool is significantly lower than the three methods from AEROWIN v1.0.

Table 16: Comparison of fraction of sorption of chlorinated paraffins to atmospheric particulates

	Fraction bound to atmospheric particulates (phi)

Example structure	Junge-Pankow method	Mackay method	K_{OA} method	OECD LRTP Tool
MCCP-1	0.019	0.042	0.017	0.007
MCCP-2	0.040	0.084	0.020	0.009
MCCP-3	0.272	0.453	0.482	0.284
MCCP-4	0.443	0.638	0.528	0.334
SCCP-1	0.0015	0.0032	0.0006	0.0002
SCCP-2	0.0067	0.0147	0.0008	0.0003
SCCP-3	0.069	0.142	0.120	0.055
SCCP-4	0.251	0.426	0.161	0.076

Figure 4: Comparison of fraction of sorption of CPs to atmospheric particulates



Appendix 5: Summary of environmental monitoring data

The following tables outline the available environmental monitoring data for “MCCPs” in surface water, sediment and biota taken from EA (2019). It should be noted that that data prior to 1995 rely on semi-quantitative analytical methods, so the specific values should be treated with caution.

Table 17: Summary of levels of “MCCPs” in surface water and sludge

Location	Year/Comment	Units	Concentration	Reference
Derwent Reservoir	1986	µg/L	1.46	ICI (1992)
River Trent, Newark	1986	µg/L	0.86	ICI (1992)
Trent Mersey Canal	1986	µg/L	0.62	ICI (1992)
River Derwent, Derby	1986	µg/L	0.64	ICI (1992)
Walton on Trent	1986	µg/L	1.07	ICI (1992)
River Ouse, Goole	1986	µg/L	0.94	ICI (1992)
River Don, Rotherham	1986	µg/L	1.13	ICI (1992)
River Aire/Ouse	1986	µg/L	1.13	ICI (1992)
River Ouse, York	1986	µg/L	1.36	ICI (1992)
River Cover, Wilton	1986	µg/L	0.84	ICI (1992)
River Ure, Mickley	1986	µg/L	1.46	ICI (1992)
River Trent, Gainsborough	1986	µg/L	2.49	ICI (1992)
River Trent, Burton	1986	µg/L	2.46	ICI (1992)
River Rother	1986	µg/L	2.11	ICI (1992)
River Trent, Humber	1986	µg/L	3.75	ICI (1992)
Hull Docks	1986	µg/L	2.69	ICI (1992)
River Lech at Augsburg	1987	µg/L		Ballschmiter (1994)
	1994		<0.05	
River Lech at Gersthofen (upstream from a CP production site)	1987	µg/L	4.5	Ballschmiter (1994)
	1994		0.094	
	1987	µg/L	4	

Location	Year/Comment	Units	Concentration	Reference
River Lech at langweid (downstream from a CP production site)	1994		0.185	Ballschmiter (1994)
River Lech at Rain	1987	µg/L		Ballschmiter (1994)
	1994		0.170	
River Danube at Marxheim (downstream from the mouth of the River Lech)	1987	µg/L	20	Ballschmiter (1994)
	1994		0.072	
River Danube at Marxheim (upstream from the mouth of the River Lech)	1987	µg/L	4	Ballschmiter (1994)
	1994		≤0.055	
Irish Sea: Site a	Relates to C_{10-20}	µg/L	1	Campbell and McConnell (1980)
Irish Sea: Site b	Relates to C_{10-20}	µg/L	0.5	Campbell and McConnell (1980)
Irish Sea: Site c	Relates to C_{10-20}	µg/L	0.5	Campbell and McConnell (1980)
Irish Sea: Site d	Relates to C_{10-20}	µg/L	0.5	Campbell and McConnell (1980)
Irish Sea: Site e	Relates to C_{10-20}	µg/L	not detected	Campbell and McConnell (1980)
Irish Sea: Site f	Relates to C_{10-20}	µg/L	not detected	Campbell and McConnell (1980)
Barmouth Harbour	Relates to C_{10-20}	µg/L	0.5	Campbell and McConnell (1980)
Menai Straights (Caernarvon)	Relates to C_{10-20}	µg/L	0.5	Campbell and McConnell (1980)
Tremadoc Bay (Llandanwg)	Relates to C_{10-20}	µg/L	not detected	Campbell and McConnell (1980)
North Minch: Ardmair	Relates to C_{10-20}	µg/L	0.5	Campbell and McConnell (1980)

Location	Year/Comment	Units	Concentration	Reference
North Minch: Port Bùn á Ghlinne	Relates to C_{10-20}	µg/L	not detected	Campbell and McConnell (1980)
North Minch: Port of Ness	Relates to C_{10-20}	µg/L	0.5	Campbell and McConnell (1980)
Goile Chròic (Lewis)	Relates to C_{10-20}	µg/L	0.5	Campbell and McConnell (1980)
Sound of Taransay (Harris)	Relates to C_{10-20}	µg/L	4.0	Campbell and McConnell (1980)
Sound of Arisaig	Relates to C_{10-20}	µg/L	1.0	Campbell and McConnell (1980)
North Sea: N55º 5.7' W1º 9.3'	Relates to C_{10-20}	µg/L	not detected	Campbell and McConnell (1980)
North Sea: N57º 26.2' W1º 17.0'	Relates to C_{10-20}	µg/L	not detected	Campbell and McConnell (1980)
North Sea: N57º 56.5' W1º 22.0'	Relates to C_{10-20}	µg/L	not detected	Campbell and McConnell (1980)
River Banwy, Llangadfan	Relates to C_{10-20}	µg/L	0.5	Campbell and McConnell (1980)
River Lea, Welwyn	Relates to C_{10-20}	µg/L	not detected	Campbell and McConnell (1980)
River Lea, Batford	Relates to C_{10-20}	µg/L	not detected	Campbell and McConnell (1980)
River Clwyd, Ruthin	Relates to C_{10-20}	µg/L	not detected	Campbell and McConnell (1980)
Bala Lake	Relates to C_{10-20}	µg/L	1.0	Campbell and McConnell (1980)
River Dee, Corwen	Relates to C_{10-20}	µg/L	not detected	Campbell and McConnell (1980)
River Wnion, Merioneth	Relates to C_{10-20}	µg/L	0.5	Campbell and McConnell (1980)
Firth of Lorne, Ganevan	Relates to C_{10-20}	µg/L	0.5	Campbell and McConnell (1980)

Location	Year/Comment	Units	Concentration	Reference
Loch Linnhe, Corran Narrows	Relates to C_{10-20}	µg/L	not detected	Campbell and McConnell (1980)
Firth of Clyde, Ashcraig	Relates to C_{10-20}	µg/L	not detected	Campbell and McConnell (1980)
Firth of Clyde, Girvan	Relates to C_{10-20}	µg/L	0.5	Campbell and McConnell (1980)
An Garbh Allt	Relates to C_{10-20}	µg/L	0.5	Campbell and McConnell (1980)
Five drinking water reservoirs, Manchester area	Relates to C_{10-20}	µg/L	not detected	Campbell and McConnell (1980)
River Aire, Leeds	Relates to C_{10-20}	µg/L	2.0	Campbell and McConnell (1980)
River Aire, Woodlesford	Relates to C_{10-20}	µg/L	2.0	Campbell and McConnell (1980)
River Ouse, Boothberry edge	Relates to C_{10-20}	µg/L	1 - 2	Campbell and McConnell (1980)
River Trent, West Bromwich	Relates to C_{10-20}	µg/L	1 - 2	Campbell and McConnell (1980)
River Trent, Walton-upon-Trent	Relates to C_{10-20}	µg/L	2 - 3	Campbell and McConnell (1980)
River Trent, Swarkestone	Relates to C_{10-20}	µg/L	1 - 2	Campbell and McConnell (1980)
River Trent, Newark	Relates to C_{10-20}	µg/L	4.0	Campbell and McConnell (1980)
River Trent, Gainsborough	Relates to C_{10-20}	µg/L	2.0	Campbell and McConnell (1980)
River Trent, confluence with Humber	Relates to C_{10-20}	µg/L	6.0	Campbell and McConnell (1980)
Humber Estuary, Hull	Relates to C_{10-20}	µg/L	1 - 2	Campbell and McConnell (1980)

Location	Year/Comment	Units	Concentration	Reference
Humber Estuary, Grimsby	Relates to C_{10-20}	µg/L	3.0	Campbell and McConnell (1980)
Mersey Estuary, New Brighton	Relates to C_{10-20}	µg/L	3.0	Campbell and McConnell (1980)
Mersey Estuary, Liverpool Pier Head	Relates to C_{10-20}	µg/L	4.0	Campbell and McConnell (1980)
River Thames, Oxford	Relates to C_{10-20}	µg/L	2.0	Campbell and McConnell (1980)
River Thames, Sanford	Relates to C_{10-20}	µg/L	1 - 2	Campbell and McConnell (1980)
Wyre Estuary	Relates to C_{10-20}	µg/L	not detected - 1.5	Campbell and McConnell (1980)
River Tees, Low Dinsdale	Relates to C_{10-20}	µg/L	not detected	Campbell and McConnell (1980)
River Tees, North Gare breakwater	Relates to C_{10-20}	µg/L	0.5	Campbell and McConnell (1980)
River Tees, Middlesbrough	Relates to C_{10-20}	µg/L	not detected	Campbell and McConnell (1980)
Sugar Creek, upstream of discharge		µg/L (particulate)	not detected	Murray *et al.* (1987a and 1987b)
Sugar Creek, just upstream of discharge		µg/L (particulate)	0.05 - 0.17	Murray *et al.* (1987a and 1987b)
Sugar Creek, just downstream of discharge		µg/L (particulate)	0.16 - 0.2	Murray *et al.* (1987a and 1987b)
Sugar Creek, downstream of discharge		µg/L (particulate)	0.20 - 0.24	Murray *et al.* (1987a and 1987b)
Upstream of sewage treatment plant, Germany		µg/L	not detected	Rieger and Ballschmiter (1995)

Location	Year/Comment	Units	Concentration	Reference
Downstream of sewage treatment plant, Germany		µg/L	not detected	Rieger and Ballschmiter (1995)
Tibutary, upstream of sewage treatment plant, Germany		µg/L	not detected	Rieger and Ballschmiter (1995)
Downstream of a chlorinated paraffin manufacturing plant, Canada		µg/L	<1	Tomy *et al.* (1998)
Surface water near to industrial sites, UK	1998	µg/L	<0.1	Cefas (1999)
Water samples from Norway	Two samples. Concentration refers to total (dissolved + particulate) in one sample. The concentrations present in the other sample was much lower (shown graphically only but was probably <0.1 µg/L.	µg/L	1.49	Petersen *et al.* (2006)
Filtered river water samples, Europe	8 Samples filtered using a membrane glass fibre filter before analysis	µg/L	<0.10	Coelhan (2009 & 2010)
Influent to waste water treatment plants, Europe	15 Samples. “MCCPs” detectable in 12 samples.	µg/L (particulate)	not detected – 4.6	Coelhan (2009 & 2010)

Location	Year/Comment	Units	Concentration	Reference
Effluent from waste water treatment plants, Norway	Samples from 8 waste water treatment plants (4 samples from each location). “MCCPs” detectable in 13% of samples analysed.	µg/L	not detected – 0.942	Thomas *et al.* (2011)
Dewatered sludge from waste water treatment plants, Norway	Samples from 8 waste water treatment plants (4 samples from each location). “MCCPs” detectable in all samples.	µg/kg	14 - 7 000 (median 385)	Thomas *et al.* (2011)
Snow (melted) from urban areas of Gothenburg, Sweden	8 Samples. “MCCPs” detectable in 2 samples (the concentrations may relate to SCCPs + MCCPs in the samples)	µg/L	0.33 - 32	Björklund *et al.* (2011)
Great Lakes Basin	Mean concentration based on an analysis of published studies	µg/L	9×10^{-7}	Klečka *et al.* (2010)
Norway	Storm water	µg/L	0.0685	Ruus *et al.* (2018)
Inner Oslofjord Norway	2017 Storm water	µg/L	0.0685	Ruus *et al*. (2018)
Sludge Norway	average (minimum-maximum)	µg/kg	4 031 (120-17 000)	Norsk Vann (2018)
Sludge Norway	average (minimum-maximum)	µg/kg	3 964 (77-11 800)	Fjeld (2005)
Effluent water, Bekkelaget STP, Norway	2017	µg/L	0.08	Ruus *et al.* (2018)

Location	Year/Comment	Units	Concentration	Reference
Sludge, Bekkelaget STP, Norway	2017	ng/g dw	2470-2500	Ruus *et al*. (2018)
Shanghai river system, China	2016 (n=74) mean (min-max)	ng/L	939 (40.3 - 3 870)	Wang *et al.* (2019)
Xiaoqing River/ Laizhou Bay, China	2014 (n=30) water column mean (min-max)	ng/L	27 (4.0–120)	Pan *et al.* (2021)
Australia (Sewage sludge)	2017	ng/g dw	542 - 3645	Brandsma *et al.* (2017)
Chinese Bohai Sea	34 seawater samples: dissolved phase; particulate phase	ng/L	9.6 to 110 6.0 to 42	Ma *et al.* (2018)

Table 18: Summary of levels of "MCCPs" in sediment and soil

Location	Year/ Comment	Units	Concentration	Reference
River Lech, upstream from chlorinated paraffin production plant	1987	µg/kg dw	2200	Unpublished (1987) [reference no longer attributable]
	1994	µg/kg dw	<10	Ballschmiter (1994)
River Lech, downstream from chlorinated paraffin production plant	1987	µg/kg dw	1 700	Unpublished (1987) [reference no longer attributable]
	1994	µg/kg dw	325	Ballschmiter (1994)
Bodensee (middle) - 0 to 5 cm depth	1994	µg/kg dw	70	Ballschmiter (1994)
River Rhein (141 km) at Rheinfelden	1994	µg/kg dw	60	Ballschmiter (1994)
River Rhein (152 km) at Rheinfelden, upper layer	1994	µg/kg dw	140	Ballschmiter (1994)
River Rhein (152 km) at Rheinfelden, lower layer	1994	µg/kg dw	85	Ballschmiter (1994)
River Rhein (853.8 km), near German-Dutch border	1994	µg/kg dw	205	Ballschmiter (1994)
River Rhein (863.8 km), near German-Dutch border	1994	µg/kg dw	145	Ballschmiter (1994)
River Main (16.2 km)	1994	µg/kg dw	260	Ballschmiter (1994)
River Main (at Griesheim)	1994	µg/kg dw	190	Ballschmiter (1994)
River Main (55 km)	1994	µg/kg dw	160	Ballschmiter (1994)
Outer Alster, Hamburg	1994	µg/kg dw	370	Ballschmiter (1994)

Location	Year/ Comment	Units	Concentration	Reference
River Elbe, Hamburg (610 km)	1994	µg/kg dw	130	Ballschmiter (1994)
River Elbe, Hamburg (629.9 km)	1994	µg/kg dw	230	Ballschmiter (1994)
River Danube, downstream of the confluence with the River Lech		µg/kg dw	1800	BUA (1992)
Irish Sea: Site a	Relates to C_{10-20}	µg/kg	100	Campbell and McConnell (1980)
Irish Sea: Site b	Relates to C_{10-20}	µg/kg	not detected	Campbell and McConnell (1980)
Irish Sea: Site c	Relates to C_{10-20}	µg/kg	not measured	Campbell and McConnell (1980)
Irish Sea: Site d	Relates to C_{10-20}	µg/kg	100	Campbell and McConnell (1980)
Irish Sea: Site e	Relates to C_{10-20}	µg/kg	not detected	Campbell and McConnell (1980)
Irish Sea: Site f	Relates to C_{10-20}	µg/kg	not detected	Campbell and McConnell (1980)
Barmouth Harbour	Relates to C_{10-20}	µg/kg	500	Campbell and McConnell (1980)
Menai Straights (Caernarvon)	Relates to C_{10-20}	µg/kg	not detected	Campbell and McConnell (1980)
Tremadoc Bay (Llandanwg)	Relates to C_{10-20}	µg/kg	not detected	Campbell and McConnell (1980)
North Minch: Ardmair	Relates to C_{10-20}	µg/kg	not detected	Campbell and McConnell (1980)
North Minch: Port Bùn á Ghlinne	Relates to C_{10-20}	µg/kg	not detected	Campbell and McConnell (1980)
North Minch: Port of Ness	Relates to C_{10-20}	µg/kg	not detected	Campbell and McConnell (1980)
Goile Chròic (Lewis)	Relates to C_{10-20}	µg/kg	not detected	Campbell and McConnell (1980)
Sound of Taransay (Harris)	Relates to C_{10-20}	µg/kg	not detected	Campbell and McConnell (1980)
Sound of Arisaig	Relates to C_{10-20}	µg/kg	not detected	Campbell and McConnell (1980)
North Sea: N55º 5.7' W1º 9.3'	Relates to C_{10-20}	µg/kg	not detected	Campbell and McConnell (1980)

Location	Year/ Comment	Units	Concentration	Reference
North Sea: N57º 26.2' W1º 17.0'	Relates to C_{10-20}	µg/kg	not detected	Campbell and McConnell (1980)
North Sea: N57º 56.5' W1º 22.0'	Relates to C_{10-20}	µg/kg	50	Campbell and McConnell (1980)
River Banwy, Llangadfan	Relates to C_{10-20}	µg/kg	not detected	Campbell and McConnell (1980)
River Lea, Batford	Relates to C_{10-20}	µg/kg	1 000	Campbell and McConnell (1980)
River Clwyd, Ruthin	Relates to C_{10-20}	µg/kg	not detected	Campbell and McConnell (1980)
River Dee, Corwen	Relates to C_{10-20}	µg/kg	300	Campbell and McConnell (1980)
River Wnion, Merioneth	Relates to C_{10-20}	µg/kg	not detected	Campbell and McConnell (1980)
Five drinking water reservoirs, Manchester area	Relates to C_{10-20}	µg/kg	not detected	Campbell and McConnell (1980)
River Aire, Leeds	Relates to C_{10-20}	µg/kg	10 000	Campbell and McConnell (1980)
River Ouse, Goole	Relates to C_{10-20}	µg/kg	2 000	Campbell and McConnell (1980)
River Trent, West Bromwich	Relates to C_{10-20}	µg/kg	6 000	Campbell and McConnell (1980)
River Trent, Walton-upon-Trent	Relates to C_{10-20}	µg/kg	1 000	Campbell and McConnell (1980)
River Trent, Swarkestone	Relates to C_{10-20}	µg/kg	14 000	Campbell and McConnell (1980)
River Trent, Newark	Relates to C_{10-20}	µg/kg	8 000	Campbell and McConnell (1980)
River Trent, Gainsborough	Relates to C_{10-20}	µg/kg	3 000	Campbell and McConnell (1980)
Humber Estuary, Hull	Relates to C_{10-20}	µg/kg	2 000	Campbell and McConnell (1980)
Humber Estuary, Stone Creek	Relates to C_{10-20}	µg/kg	2 000	Campbell and McConnell (1980)
Mersey Estuary, New Brighton	Relates to C_{10-20}	µg/kg	3 000	Campbell and McConnell (1980)

Location	Year/ Comment	Units	Concentration	Reference
Mersey Estuary, Liverpool Pier Head	Relates to C_{10-20}	µg/kg	8 000	Campbell and McConnell (1980)
River Thames, Sanford	Relates to C_{10-20}	µg/kg	1 000	Campbell and McConnell (1980)
Wyre Estuary	Relates to C_{10-20}	µg/kg	not detected - 1 600	Campbell and McConnell (1980)
Mersey Estuary, 14 sediment samples	Relates to C_{10-20}	µg/kg	not detected	Campbell and McConnell (1980)
River Tees, Low Dinsdale	Relates to C_{10-20}	µg/kg	300	Campbell and McConnell (1980)
River Tees, North Gare breakwater	Relates to C_{10-20}	µg/kg	50	Campbell and McConnell (1980)
River Tees, Middlesbrough	Relates to C_{10-20}	µg/kg	15 000	Campbell and McConnell (1980)
Japan	1979 – no information on type	µg/kg	600 - 10 000	Environment Agency Japan (1991)
Japan	1980 – no information on type	µg/kg	500 - 8 500	Environment Agency Japan (1991)
Downstream of production site, US		µg/kg dw	6.8 - 8.2	Murray *et al.* (1987a and 1987b)
Rotterdam harbour mud		µg/kg	7 - 10	Greenpeace (1995)
Hamburg harbour mud		µg/kg	8	Greenpeace (1995)
Mud flats, Kaiser Wilhelm Koog		µg/kg	98	Greenpeace (1995)
Mud flats, Den Helder		µg/kg	3	Greenpeace (1995)
St. Lawrence River, Canada, downstream of a chlorinated paraffin manufacturing plant		µg/kg dw	<3 500	Tomy *et al.* (1998)

Location	Year/ Comment	Units	Concentration	Reference
Industrial areas of the UK	A total of 77 samples from 1998. Highest concentration, downstream of a lubricant blending/metal working site.	µg/kg dw	65 000	Cefas (1999)
Mersey and Seine estuaries	Mean levels of total CPs - predominantly LCCPs (only traces of “MCCPs” present)	µg/kg dw	10.5	van Zeijl (1997)
Schelde estuary	Mean levels of total CPs - predominantly LCCPs (only traces of “MCCPs” present)	µg/kg dw	5.5	van Zeijl (1997)
Liffey River estuary	Mean levels of total CPs - predominantly LCCPs (only traces of “MCCPs” present)	µg/kg dw	4.8	van Zeijl (1997)
Forth estuary	Mean levels of total CPs - predominantly LCCPs (only traces of “MCCPs” present)	µg/kg dw	3.3	van Zeijl (1997)
Humber estuary	Mean levels of total CPs - predominantly LCCPs (only traces of “MCCPs” present)	µg/kg dw	1.2	van Zeijl (1997)
Sediment core, Lake St. Francois, St. Lawrence River	1972	µg/kg dw	1 200	Muir *et al.* (2002)

Location	Year/ Comment	Units	Concentration	Reference
Sediment core, Lake St. Francois, St. Lawrence River	1976	µg/kg dw	1 000	Muir *et al.* (2002)
Sediment core, Lake St. Francois, St. Lawrence River	1981	µg/kg dw	700	Muir *et al.* (2002)
Sediment core, Lake St. Francois, St. Lawrence River	1986	µg/kg dw	750	Muir *et al.* (2002)
Sediment core, Lake St. Francois, St. Lawrence River	1990	µg/kg dw	400	Muir *et al.* (2002)
Sediment core, Lake St. Francois, St. Lawrence River	1995	µg/kg dw	700	Muir *et al.* (2002)
Lake Zürich		µg/kg	5	Schmid and Müller (1985)
Close to chlorinated paraffin manufacturing site, Australia	Sample I	µg/kg dw	1 108	Kemmlein *et al.* (2002)
Close to chlorinated paraffin manufacturing site, Australia	Sample II	µg/kg dw	1 168	Kemmlein *et al.* (2002)
Close to chlorinated paraffin manufacturing site, Australia	Sample II	µg/kg dw	3 108	Kemmlein *et al.* (2002)
Close to chlorinated paraffin manufacturing site, Australia	Sample IV	µg/kg dw	16 403	Kemmlein *et al.* (2002)

Location	Year/ Comment	Units	Concentration	Reference
Lake Thun, Switzerland	Sediment core, surface layer corresponding to around 2004	µg/kg dw	26	Iozza *et al.* (2008)
Czech Republic	Highest concentration	µg/kg	5 575	Pribylová *et al.* (2006)
North and Baltic Sea	Sample 1 (relates to C_{14-15} CPs)	µg/kg dw	87	Hüttig and Oehme, (2006)
North and Baltic Sea	Sample 2 (MCCP relates to C_{14-15} CPs)	µg/kg dw	48	Hüttig and Oehme, (2006)
North and Baltic Sea	Sample 3 (MCCP relates to C_{14-15} CPs)	µg/kg dw	34	Hüttig and Oehme, (2006)
North and Baltic Sea	Sample 4 (MCCP relates to C_{14-15}CPs)	µg/kg dw	149	Hüttig and Oehme, (2006)
North and Baltic Sea	Sample 5 (MCCP relates to C_{14-15} CPs)	µg/kg dw	23	Hüttig and Oehme, (2006)
North and Baltic Sea	Sample 6 (MCCP relates to C_{14-15} CPs)	µg/kg dw	43	Hüttig and Oehme, (2006)
North and Baltic Sea	Sample 7 (MCCP relates to C_{14-15} CPs)	µg/kg dw	85	Hüttig and Oehme, (2006)
North and Baltic Sea	Sample 8 (MCCP relates to C_{14-15} CPs)	µg/kg dw	72	Hüttig and Oehme, (2006)
North and Baltic Sea	Sample 9 (MCCP relates to C_{14-15} CPs)	µg/kg dw	39	Hüttig and Oehme, (2006)
North and Baltic Sea	Sample 10 (MCCP relates to C_{14-15} CPs)	µg/kg dw	22	Hüttig and Oehme, (2006)
North and Baltic Sea	Sample 11 (MCCP relates to $C_{14-15\ CPs}$)	µg/kg dw	33	Hüttig and Oehme, (2006)
North and Baltic Sea	Highest concentration - relates to SCCP+MCCP (MCCP/SCCP ratio 1.7 - 2.4)	µg/kg dw	499	Hüttig and Oehme, (2005)

Location	Year/ Comment	Units	Concentration	Reference
Firth of Clyde, Scotland	"MCCPs" detected but not quantified		detected	Hussy *et al.* (2012)
Sediments from Norway	Twenty sediments analysed	µg/kg dw	50 - 3 240	Petersen *et al.* (2006)
Pearl River Delta, South China	Range	µg/kg dw	880 to 38 000	Chen *et al.* (2011)
Pearl River Delta, South China. Pond sediments in the vicinity of an electronic waste recycling area	Mean	µg/kg dw	21 000	Chen *et al.* (2011)
Pearl River Delta, South China. River sediments from industrialised areas.	Mean	µg/kg dw	3 900	Chen *et al.* (2011)
Yellow River, China	2018 (mean, normal season)	ng/g	35	Li *et al.* (2018a)
Yellow River, China	2018 (mean, wet season)	ng/g	89	Li *et al.* (2018a)
Yellow River, China	2018 (mean, dry season)	ng/g	167	Li *et al.* (2018a)
Yellow River, China	2016	ng/g dw	44.81538462	Qiao *et al.* (2016)
Mid-lower reach of the Yellow River and tributaries, China	2014 (n = 69) surface sediment mean ± sd (min-max)	ng/g	97.1 ± 227 (1.56 - 1 558)	Li *et al.* (2018a)
Mid-lower reach of the Yellow River and tributaries, China	2014 (n = 68) suspended particulate matter mean ± sd (min-max)	ng/g	2573 ± 3250 (28.6 - 14 428)	Li *et al.* (2018a)
Pearl River Delta, China	2017	ng/g dw	102 - 6650	Zeng *et al.* (2017)
Shenzhen, China	2017	ng/g dw	10.9 - 2500	Zeng *et al.* (2017)

Location	Year/ Comment	Units	Concentration	Reference
Hong Kong, China	2017	ng/g dw	<LOD - 286	Zeng *et al.* (2017)
Tokyo Bay. Japan	2017	ng/g dw	3.2 - 56.8	Zeng *et al.* (2017)
Hong Kong, China	2004 sediment core	ng/g dw	< LOD - 20.3 (SY 2004)	Zeng *et al.* (2017)
Tokyo Bay. Japan	2012 sediment core	ng/g dw	8.0 (SY 1959) - 29.3 (SY 2010) max - 61.3 (SY 1991)	Zeng *et al.* (2017)
Tokyo Bay. Japan	2012 sediment core	ng/g dw	11.0 (SY 1940) - 7.9 (SY 2010) max – 180 (SY 1989)	Zeng *et al.* (2017)
Laizhou Bay, China	2009	ng/g dw	6 - 63	Pan *et al.* (2018)
Rivers around Laizhou Bay, China	2009	ng/g dw	1.8 - 3200	Pan *et al.* (2018)
Xiaoqing River, China	2014 (n=22) surface sediment mean (min-max)	ng/g dw	6 020 (130 - 27 000)	Pan *et al.* (2021)
Laizhou Bay, China	2014 (n=22) surface sediment mean (min-max)	ng/g dw	13 (2.4 - 9.0)	Pan *et al.* (2021)
Inner Oslofjord, Norway	2017	mg/kg dw	0.14	Ruus *et al.* (2018)
Oslo, Norway	Soil	ng/g dw	Mean = 183 Median = 193 Minimum = 57 Maximum = 282	Heimstad *et al.* (2018)
Chongming Island, China	Soil	ng/g	Minimum = 2.56 Maximum = 96.3 Median = 7.32	Sun *et al.* (2013).
Jiaojiang River, China	Soil samples within 5 km of the e-waste dismantling centres	ng/g dw	507 to 4.40×10^6	Xu *et al.* (2019)

Location	Year/ Comment	Units	Concentration	Reference
Jiaojiang River, China	Sediment samples from the surrounding area	ng/g dw	271 – 2.72×10^4	Xu *et al.* (2019)
Yangtze River, China	Sediments from the middle reaches of the Yangtze River	ng/g dw	504	Qiao *et al.* 2016
Yangtze River, China	Sediments from the middle reaches of the Yangtze River	ng/g dw	Not detected to 14.6 ng/g dw	Qiao *et al.* (2017)
Yellow River, China	Sediment samples from the middle reaches of the Yellow River	ng/g dw	20.5 – 93.7	Xia *et al.* (2016)
Pearl River Delta, South China	Soil	ng/g	Minimum = 1.95 Maximum = 188 Median = 7.98	Wang *et al.* (2014)
Switzerland	Soil	ng/g	5.1 – 160	Bogdal *et al.* (2015)
China	Core soils from Chinese nation-wide agricultural lands	ng/g dw	127 – 1969	Aamir *et al.* (2019)
Dongjiang River, China	Top soils (0−5 cm) at 60 sites	ng/g	59.3	Wang *et al.* (2013)
China	In-plant coniferous leaves and soil, 2016 (average)	ng/g dw	3481.8	Xu *et al.* (2016)
Shanghai, China	Suburb soils, 2017	ng/g dw	ND – 666	Wang *et al.* (2017)
Suburban soils, Shanghai	2011 (n=42) farmland soil median	ng/g	15.0	Wang *et al.* 2017
Suburban soils, Shanghai	2011 (n=16) wasteland soil median	ng/g	13.8	Wang *et al.* 2017
Suburban soils, Shanghai	2011 (n=27) greenland soil median	ng/g	20.4	Wang *et al.* 2017

Location	Year/ Comment	Units	Concentration	Reference
Suburban soils, Shanghai	2011 (n=16) wetland soil median	ng/g	15.4	Wang *et al.* 2017
Shanghai river system, China	2016 (n=74) sediment mean (min-max)	ng/g	947 (10.1 - 10 8000)	Wang *et al.* (2019)
Lake Bosten, China	2014 surface sediment (min - max)	ng/g dw	35 - 76	Zhang et al. (2019)
Lake Quinghai, China	2014 surface sediment	ng/g dw	120	Zhang et al. (2019)
Lake Hongfeng, China	2018 surface sediment (min - max)	ng/g dw	420 - 430	Zhang et al. (2019)
Lake Chaohu, China	2011 & 2014 surface sediment	ng/g dw	12 (SY 2011) & 30 (SY 2014)	Zhang et al. (2019)
Lake Taihu, China	2014 surface sediment (min - max)	ng/g dw	260 - 690	Zhang et al. (2019)
Lake Dianchi, China	2014 surface sediment (min - max)	ng/g dw	360 - 450	Zhang et al. (2019)
Lake Erhai, China	2014 surface sediment (min - max)	ng/g dw	230 - 1 500	Zhang et al. (2019)
Lake Bosten, China	2006 (100 years) sediment core	ng/g dw	20 (SY 1935) – max 40 (sedimentation year 2006)	Zhang et al. (2019)
Lake Quinghai, China	2006 (151 years) sediment core	ng/g dw	20 (SY 1869) – max 86 (SY 2006)	Zhang et al. (2019)
Lake Hongfeng, China	2006 (37 years) sediment core	ng/g dw	38 (SY 1969) – max 430 (SY 2006)	Zhang et al. (2019)
Lake Hongfeng, China	2019 (25 years) sediment core	ng/g dw	280 (SY 1994) - max 430 (SY 2019)	Zhang et al. (2019)

Location	Year/ Comment	Units	Concentration	Reference
Lake Sihailongwan, China	2006 (241 years) sediment core	ng/g dw	23 (SY 1841) - max 270 (SY 2006)	Zhang et al. (2019)
Lake Chaohu, China	2006 (100 years) sediment core	ng/g dw	16 (SY 1965) - 25 (SY 2006) max - 31 (SY year 1991)	Zhang et al. (2019)
Lake Chaohu, China	2011 (70 years) sediment core	ng/g dw	11 (SY 1978) - 20 (SY 2011) max - 44 (SY 2000)	Zhang et al. (2019)
Lake Taihu, China	2006 (56 years) sediment core	ng/g dw	15 (SY 1972) - 200 (SY 2006) max - 230 (SY 1986)	Zhang et al. (2019)
Lake Taihu, China	2017 sediment core	ng/g dw	110 (SY 1980) - max 850 (SY 2017)	Zhang et al. (2019)
Lake Chengai, China	2012 sediment core	ng/g dw	23 (SY 1970) - max 2 700 (SY 2006)	Zhang et al. (2019)
Lake Dianchi, China	2006 sediment core	ng/g dw	30 (SY 1927) - max 280 (SY 2006)	Zhang et al. (2019)
Lake Dianchi. China	2018 sediment core	ng/g dw	12 (SY 1961) - max 350 (SY 2018)	Zhang et al. (2019)
Lake Erhai, China	2012 sediment core	ng/g dw	30 (SY 1863) - max 470 (SY 2006)	Zhang et al. (2019)
Himmerfjärden, Sweden	2015 (135 years) sediment core - emission source sewage treatment plant	ng/g dw	< LOQ (SY 1881) - 10 (SY 2015) max - 15.0 (SY 1991)	Yuan et al. (2017)
Umeå, Sweden	2015 (61 years) sediment core - emission source wood industry	ng/g dw	< LOQ (SY 1954) - max 93 (SY 2015)	Yuan et al. (2017)
Nyköping , Sweden	2008 (126 years) sediment core - emission source steel factory	ng/g dw	< LOQ (SY 1917) - max 1200 (SY 2008)	Yuan et al. (2017)

Location	Year/ Comment	Units	Concentration	Reference
Yangkou Chemical Industrial Park, Jiangsu Province, China	2018 (n=20) Total soil (min-max)	ng/g	15.1 - 739.6	Huang et al. 2020
Yangkou Chemical Industrial Park, Jiangsu Province, China	2018 (n=4) STP soil mean (min-max)	ng/g	282 (83.1 - 591)	Huang et al. 2020
Yangkou Chemical Industrial Park, Jiangsu Province, China	2018 (n=3) Canal soil (min-max)	ng/g	100 - 740	Huang et al. 2020
Yangkou Chemical Industrial Park, Jiangsu Province, China	2018 (n=13) Road soil mean (min-max)	ng/g	133 (15.1 - 295)	Huang et al. 2020
Dongguan City, Pearl River Delta, China	2011 (n=49) surface soil samples industrial zones mean (min-max)	ng/g	369 (23.9 - 2 427)	Wu et al. 2020
Dongguan City, Pearl River Delta	2011 (n=17) reservoir sediment samples industrial zones mean (min-max)	ng/g	206 (29.1 - 601)	Wu et al. 2020
Dongguan City, Pearl River Delta	2011 (n=17) river sediment samples industrial zones mean (min-max)	ng/g	694 (14.0 - 1 581)	Wu et al. 2020

Location	Year/ Comment	Units	Concentration	Reference
Oceanic marine sediments MAREANO programme	2017 (n=5) 1 of 5 samples contained MCCPs > LOD	mg/kg	2.8	Boitsov and Klungsøyr, 2018
Oceanic marine sediments MAREANO programme	2018 (n=8) 2 of 8 samples contained MCCP > LOD	ng/g	1. 410 Kongsfjorden 2. 536 Rijpfjorden 3. 1376 Svalbard (2017 samples) 4. 655 Svalbard (2017 samples)	Boitsov et al. 2019
Oceanic marine sediments MAREANO programme	2019 (n=10)	ng/g	< LOD in all sediments	Boitsov and Sanden, 2020

Table 19: Summary of levels of "MCCPs" in biota (and some foodstuffs)

Sample	Location	Comment	Units	Level	Reference
Mussel	United Kingdom	Mean concentration – relates to C_{10-20}	µg/kg	3 250	Campbell and McConnell (1980)
Plaice *Pleuronectes platessa*	United Kingdom	Mean concentration – relates to C_{10-20}	µg/kg	30	Campbell and McConnell (1980)
Pouting *Trisopterus luscus*	United Kingdom	Mean concentration – relates to C_{10-20}	µg/kg	100	Campbell and McConnell (1980)
Pike *Esox lucius*	United Kingdom	Mean concentration – relates to C_{10-20}	µg/kg	25	Campbell and McConnell (1980)
Grey Seal *Halichoerus grypus*	United Kingdom	Mean concentration – relates to C_{10-20}	µg/kg	75 (liver and blubber)	Campbell and McConnell (1980)
Grey Heron *Ardea cinerea*	United Kingdom	Relates to C_{10-20}	µg/kg	100 - 1 200 (liver)	Campbell and McConnell (1980)
Common Guillemot *Uria aalge*	United Kingdom	Relates to C_{10-20}	µg/kg	100 - 1 100 (liver)	Campbell and McConnell (1980)
Herring Gull *Larus argentatus*	United Kingdom	Relates to C_{10-20}	µg/kg	200 – 900 (liver)	Campbell and McConnell (1980)
Seabirds' eggs	United Kingdom	Relates to C_{10-20}	µg/kg	up to 2 000	Campbell and McConnell (1980
Dairy products	United Kingdom	Mean concentration – relates to C_{10-20}	µg/kg	300	Campbell and McConnell (1980)
Vegetable oils and derivatives	United Kingdom	Mean concentration – relates to C_{10-20}	µg/kg	150	Campbell and McConnell (1980)
Fruit and vegetables	United Kingdom	Mean concentration – relates to C_{10-20}	µg/kg	5	Campbell and McConnell (1980)

Sample	Location	Comment	Units	Level	Reference
Beverages	United Kingdom	Mean concentration – relates to C_{10-20}	µg/kg	not detected	Campbell and McConnell (1980)
Domestic Sheep *Ovis aries*	United Kingdom, remote from industry	Relates to C_{10-20}	µg/kg	not detected in liver, brain kidney, mesenteric fat	Campbell and McConnell (1980)
	United Kingdom, close to chlorinated paraffin production site			200 (liver); 50 (mesenteric fat); 50 (kidney); not detected in heart, lung or perinephritic fat	
Mussel	Upstream of CP production site		µg/kg	<7	Murray *et al*. (1987a)
	Downstream of CP production site			170	
Mackerel			µg/kg lw	46	Greenpeace (1995)
Herring oil			µg/kg lw	12	Greenpeace (1995)
Margarine containing fish oil			µg/kg lw	28	Greenpeace (1995)
Common Porpoise *Phocoena phocoena*			µg/kg lw	3 - 7	Greenpeace (1995)
Fin Whale *Balaenoptera physalus*			µg/kg lw	144	Greenpeace (1995)
Pork			µg/kg lw	11	Greenpeace (1995)

Sample	Location	Comment	Units	Level	Reference
Cow's milk			µg/kg lw	16	Greenpeace (1995)
Rabbit *Oryctolagus cuniculus*	Revingehed, Skåne, Sweden 1986	Unspecified chain length, with 6-16 chlorine atoms/molecule	µg/kg lw	2 900 (muscle)	Jansson *et al.* (1993)
Moose *Alces alces*	Grimsö, Västtmanland, Sweden 1985 - 86	Unspecified chain length, with 6-16 chlorine atoms/molecule	µg/kg lw	4 400 (muscle)	Jansson *et al.* (1993)
Reindeer *Rangifer tarandus*	Ottsjö, Jämtland, Sweden 1986	Unspecified chain length, with 6-16 chlorine atoms/molecule	µg/kg lw	140 (suet)	Jansson *et al.* (1993)
Osprey *Pandion haliaetus*	Sweden, 1982 - 1986	Unspecified chain length, with 6-16 chlorine atoms/molecule	µg/kg lw	530 (muscle)	Jansson *et al.* (1993)
Arctic Char *Salvelinus alpinus*	Lake Vättern, Central Sweden, 1987	Unspecified chain length, with 6-16 chlorine atoms/molecule	µg/kg lw	570 (muscle)	Jansson *et al*. (1993)
Whitefish *Coregonus sp.*	Lake Storvindeln, Lapland, 1986	Unspecified chain length, with 6-16 chlorine atoms/molecule	µg/kg lw	1 000 (muscle)	Jansson *et al*. (1993)
Herring *Clupea harengus*	Bothnian Sea, Sweden 1986	Unspecified chain length, with 6-16 chlorine atoms/molecule	µg/kg lw	1 400 (muscle)	Jansson *et al*. (1993)
	Baltic proper, Sweden 1987			1 500 (muscle)	
	Skagerrak, Sweden 1987			1 600 (muscle)	

Sample	Location	Comment	Units	Level	Reference
Ringed Seal *Pusa hispida*	Kongsfjorden, Svalbard 1981	Unspecified chain length, with 6-16 chlorine atoms/molecule	µg/kg lw	130 (blubber)	Jansson *et al*. (1993)
Grey Seal *Halichoerus grypus*	Baltic Sea, Sweden 1979 - 85	Unspecified chain length, with 6-16 chlorine atoms/molecule	µg/kg lw	280 (blubber)	Jansson *et al*. (1993)
Benthos	Industrial areas of the United Kingdom 1998	Highest concentration - tentatively identified as MCCPs	µg/kg	800	Cefas (1999)
Fish	Industrial areas of the United Kingdom 1998	Highest concentration - tentatively identified as MCCPs	µg/kg	2 800 (pike liver)	Cefas (1999)
Human milk			µg/kg lw	7	Greenpeace (1995)
Human milk	Lancaster and London, UK	Highest concentration	µg/kg lw	61	Thomas and Jones (2002)
Human milk	Lancaster and London, UK	95th percentile	µg/kg lw	127.5	Thomas *et a*l. (2006)
Human milk	Bavaria	60 Samples. “MCCPs” detected in 58% of the samples. Range reflects the quantified levels.	µg/kg lw	9.6 - 903 [median 115.4]	Hilger *et al*. (2011)
Human milk	China	2007 (median value)	µg/kg lw	60.4	Xia *et al*. (2017)
Human milk	China	2011 (median value)	µg/kg lw	64.3	Xia *et al*. (2017)
Human blood	China	2017	µg/kg lw	130 - 3200	Li *et al*. (2017)

Sample	Location	Comment	Units	Level	Reference
Human placenta	China	2018	µg/kg lw	80.8 - 954	Wang *et al*. (2018)
Cows' milk	Lancaster, UK		µg/kg lw	63	Thomas and Jones (2002)
Butter	Denmark		µg/kg lw	11	Thomas and Jones (2002)
	Wales			8.8	
	Ireland			52	
Beluga Whale *Delphinapterus leucas*	St. Lawrence River, Canada	Blubber samples from 15 females	µg/kg ww	79 000 (max.)	Bennie *et al.* (2000)
		Blubber samples from 10 males		80 000 (max.)	
		Liver samples from 3 females		20 900 (max.)	
		Liver samples from 3 males		5 820 (max.)	
Carp	Lake Ontario, Canada	Whole body homogenates from 3 individuals	µg/kg ww	563 (max.)	Bennie *et al.* (2000)
Trout	Lake Ontario, Canada	Whole body homogenates from 10 individuals	µg/kg ww	4 390 (max.)	Bennie *et al.* (2000)
Mussel	Close to a chlorinated paraffin manufacturing plant in Australia		µg/kg lw	23 200	Kemmlein *et al.* (2002)
Crabs	Close to a chlorinated paraffin manufacturing plant in Australia		µg/kg lw	30 500	Kemmlein *et al.* (2002)
Lake Trout *Salvelinus namaycush*	Lake Ontario	Archived samples from 1998	µg/kg	25	Ismail *et al*. (2009)
		Archived samples from 2004		8	

Sample	Location	Comment	Units	Level	Reference
Diporeia	Lake Ontario	Mean concentration, 2001	µg/kg	12	Muir *et al.* (2002)
Rainbow Smelt *Osmerus mordax*	Lake Ontario	Mean concentration, 2001	µg/kg	109	Muir *et al.* (2002)
Slimy Sculpin *Cottus cognatus*	Lake Ontario	Mean concentration, 2001	µg/kg	108	Muir *et al.* (2002)
Alewife *Alosa pseudoharengus*	Lake Ontario	Mean concentration, 2001	µg/kg	35	Muir *et al.* (2002)
Lake Trout *Salvelinus namaycush*	Lake Ontario	Mean concentration, 2001	µg/kg	15	Muir *et al.* (2002)
Plankton	Lake Ontario	Mean concentration, 1999 - 2004	µg/kg	not detected	Houde *et al.* (2008)
	Lake Michigan			not detected	
Diporeia	Lake Ontario	Mean concentration, 1999 - 2004	µg/kg	4.2	Houde *et al.* (2008)
	Lake Michigan			not detected	
Mysis	Lake Ontario	Mean concentration, 1999 - 2004	µg/kg	not detected	Houde *et al.* (2008)
	Lake Michigan			not detected	
Rainbow Smelt *Osmerus mordax*	Lake Ontario	Mean concentration, 1999 - 2004	µg/kg	109	Houde *et al.* (2008)
	Lake Michigan			not detected	
Slimy Sculpin *Cottus cognatus*	Lake Ontario	Mean concentration, 1999 - 2004	µg/kg	108	Houde *et al.* (2008)
	Lake Michigan			2.9	
Alewife *Alosa pseudoharengus*	Lake Ontario	Mean concentration, 1999 - 2004	µg/kg	35	Houde *et al.* (2008)
	Lake Michigan			5.6	
Lake Trout *Salvelinus namaycush*	Lake Ontario	Mean concentration, 1999 - 2004	µg/kg	24	Houde *et al.* (2008)
	Lake Michigan			5.6	

Sample	Location	Comment	Units	Level	Reference
Dab, cod and flounder	North and Baltic Sea	Highest	µg/kg	260 (liver)	Reth *et al*. (2005)
Atlantic Cod *Gadus morhua*	Iceland and Norway	Highest concentration	µg/kg	47 (liver)	Reth *et al.* (2006)
Arctic Char *Salvelinus alpinus*	Bear Island	Highest concentration	µg/kg	43 (liver) 47 (muscle)	Reth *et al.* (2006)
Little Auk *Alle alle*	Bear Island	Highest concentration	µg/kg	370 (liver) 55 (muscle)	Reth *et al.* (2006)
Black-legged Kittiwake *Rissa tridactyla*	Bear Island	Highest concentration	µg/kg	39 (liver) 38 (muscle)	Reth *et al.* (2006)
Spruce needles	The Alps	Eight samples collected in October 2004. Concentrations refer to “MCCPs”.	µg/kg	5.2 - 95	Iozza *et al.* (2009a)
Spruce needles	The Alps	Samples from various altitudes from 7 locations collected in Autumn 2004. Concentrations refer to total CPs	µg/kg	26 - 450	Iozza *et al.* (2009b)
Masson pine needles	Shanghai, China	2016	µg/kg	12.4 – 33 500	Wang *et al.* (2016)
“Biota”	Great Lakes Basin	Mean concentration based on an analysis of published studies	µg/kg	21	Klečka *et al.* (2010)
Porpoises	South China Sea	2004 - 2014	µg/kg dw	320 – 8 600	Zeng *et al.* (2015)

Sample	Location	Comment	Units	Level	Reference
Dolphins	South China Sea	2004 - 2014	µg/kg dw	530 – 23 000	Zeng *et al.* (2015)
Bastard halibut	Liaodong Bay, North China	2017	µg/kg lw	706.5 ± 240.2	Huang *et al.* (2017)
Turbot	Liaodong Bay, North China	2017	µg/kg lw	5 097 ± 2 242	Huang *et al.* (2017)
Ray	Liaodong Bay, North China	2017	µg/kg lw	109.0 ± 44.6	Huang *et al.* (2017)
Navodon septentrionalis	Liaodong Bay, North China	2017	µg/kg lw	375.9 ± 120.2	Huang *et al.* (2017)
Yellow croaker	Liaodong Bay, North China	2017	µg/kg lw	55.19 ± 23.73	Huang *et al.* (2017)
Bass	Liaodong Bay, North China	2017	µg/kg lw	24.57 ± 10.31	Huang *et al.* (2017)
Capelin	Liaodong Bay, North China	2017	µg/kg lw	30.26 ± 11.49	Huang *et al.* (2017)
Spanish Mackerel	Liaodong Bay, North China	2017	µg/kg lw	53.92 ± 22.64	Huang *et al.* (2017)
Abalone	Liaodong Bay, North China	2017	µg/kg lw	63.48 ± 24.75	Huang *et al.* (2017)
Cod	Liaodong Bay, North China	2017	µg/kg lw	22.37 ± 9.17	Huang *et al.* (2017)
Common Barbel *Barbus barbus*	Chéran River (mean)	2019	µg/kg lw	7 123	Labadie *et al.* (2019)
	Usses River (mean)			4 615	

Sample	Location	Comment	Units	Level	Reference
	Combeauté River (mean)			5 423	
	Rhône River (mean)			904	
	Morge Canal (mean)			3 292	
Earthworms	Oslo, Norway	2017	µg/kg ww	Mean: 37 Median: 39 Minimum: 25 Maximum: 46	Heimstad *et al.* (2018)
Fieldfare *Turdus pilaris*	Oslo, Norway	2017, eggs	µg/kg ww	Mean: 21 Median: 7.35 Minimum: 4.70 Maximum: 135	Heimstad *et al.* (2018)
Eurasian Sparrowhawk *Accipter nisus*	Oslo, Norway	2017, eggs	µg/kg ww	Mean: 12.2 Median: <LOD Minimum: <LOD Maximum: 74.0	Heimstad *et al.* (2018)
Tawny Owl *Strix aluco*	Oslo, Norway	2017, eggs	µg/kg ww	Mean: <LOD Median: <LOD Minimum: <LOD Maximum: <LOD	Heimstad *et al.* (2018)
Rat *Rattus norvegicus*	Oslo, Norway	2017, liver	µg/kg ww	Mean: 183 Median: 177 Minimum: 81.0 Maximum: 327	Heimstad *et al.* (2018)

Sample	Location	Comment	Units	Level	Reference
Red Fox *Vulpes vulpes*	Oslo, Norway	2017, liver	µg/kg ww	Mean: 68.1 Median: 61 Minimum: 23 Maximum: 130	Heimstad *et al.* (2018)
Badger *Meles meles*	Oslo, Norway	2017, liver	µg/kg ww	Mean: 43 Median: 41 Minimum: 37 Maximum: 51	Heimstad *et al.* (2018)
Blue Mussel *Mytilus edulis*	Gresshol men, Inner Oslofjord, Norway	2017	µg/kg ww	Median: 11.9	Green *et al.* (2018)
	Færder, Outer Oslofjord, Norway			Median: 9.89	
	Singlekalv en, Hvaler, Norway			Median: 5.82	
	Bjørkøya, Langesun d-fjord, Norway			Median: 22.7	
	Sylterøya, Langesun d-fjord, Norway			Median: 10.5	
	Nordnes, Bergen harbour, Norway			Median: 44.9	
	Vågsvåg, Outer Nordfjord, Norway			Median: 27.3	
	Ålesund harbour, Norway			Median: 41.6	

Sample	Location	Comment	Units	Level	Reference
	Ørland area, Outer Trondheims-fjord, Norway			Median: 4.46	
	Bodø harbour, Norway			Median: 52.4	
	Mjelle, Bodø area, Norway			Median: 17.3	
	Svolvær airport area, Norway			Median: 22.2	
Atlantic Cod *Gadus morhua*	Inner Oslofjord, Norway	2017, liver	µg/kg ww	Median: 498.0	Green *et al.* (2018)
	Tjøme, Outer Oslofjord, Norway			Median: 35.15	
	Kirkøy, Hvaler, Norway			Median: 77.2	
	Stathelle area, Langesund-fjord, Norway			Median: 143.0	
	Kristiansand harbour area, Norway			Median: 226.5	
	Inner Sørfjord, Norway			Median: 100.0	
	Bømlo, Outer Selbjørnfjord, Norway			Median: 74.6	
	Bergen harbour area, Norway			Median: 310.0	

Sample	Location	Comment	Units	Level	Reference
	Ålesund harbour area, Norway			Median: 842.0	
	Trondheim harbour, Norway			Median: 102.0	
	Austnesfjord, Lofoten, Norway			Median: 71.6	
	Tromsø harbour area, Norway			Median: 123.0	
	Isfjorden, Svalbard, Norway			Median: 35.4	
Common Eider *Somateria mollissima*	Breøyane, Kongsfjorden, Svalbard, Norway	2017	µg/kg ww	Median: 2.5 (blood)	Green *et al.* (2018)
				Median: 8.6 (egg)	
Cereal	19 Chinese provinces	1710 cereal samples giving 19 pooled samples	µg/kg ww	Mean: 213	Wang *et al.* (2019)
Legume	19 Chinese provinces	1710 legume samples giving 19 pooled samples	µg/kg ww	Mean: 184	Wang *et al.* (2019)
Herring *Clupea harengus*	Scandinavia	2011, female 4–6 years, muscle	µg/kg lw	44	Yuan *et al.* (2019)
		2014, female 4–5 years, muscle		30	
		2017, female 3–5 years, muscle		51	
		2014, female and male 7 – 13 years, liver		140	

Sample	Location	Comment	Units	Level	Reference
		2014 female and male, 7–13 years, muscle		120	
		2016 female and male, 6 – 12 years, liver		170	
		2016, female and male 6 – 12 years, muscle		140	
		2015, female adults, liver		440	
Common Eider *Somateria mollissima*	Scandinavia	2015, egg	µg/kg lw	140-200	Yuan *et al.* (2019)
		2015, female adults, liver		290	
Common Guillemot *Uria aalge*	Scandinavia	2016, egg	µg/kg lw	58-67	Yuan *et al.* (2019)
White-tailed Sea-eagle *Haliaeetus albicilla*	Scandinavia	2015, egg	µg/kg lw	140-250	Yuan *et al.* (2019)
Grey Seal *Halichoerus grypus*	Scandinavia	2006 – 2008, males juveniles (0 – 1 year)	µg/kg lw	210 (liver)	Yuan *et al.* (2019)
				83 (blubber)	
		2009 – 2010, males adults (8 – 11 year)		230 (liver)	
				32 (blubber)	
		2014 – 2015, juveniles		540 (liver)	
Harbour Seal *Phoca vitulina*	Scandinavia	2014 – 2015, juveniles, blubber	µg/kg lw	100	Yuan *et al.* (2019)
		2012 – 2016, adults		230 (liver)	
				64 (blubber)	
		2006 – 2012, 3 females and 1 male adults, liver		140 (liver)	

Sample	Location	Comment	Units	Level	Reference
Harbour Porpoise *Phocoena phocoena*	Scandinavia	2006 – 2012, 3 females and 1 male adults	µg/kg lw	36 (blubber)	Yuan *et al.* (2019)
		2008, 1 female and 1 male adults		440 (liver)	
				59 (blubber)	
Moose *Alces alces*	Scandinavia	2012 – 2015, female and male adults, muscle	µg/kg lw	1 600	Yuan *et al.* (2019)
Bank Vole *Myodes glareolus*	Scandinavia	2014, female and male adults, muscle	µg/kg lw	370	Yuan *et al.* (2019)
Eurasian Lynx *Lynx lynx*	Scandinavia	2012 – 2016 female and male adults, muscle	µg/kg lw	750	Yuan *et al.* (2019)
Grey Wolf *Canis lupus*	Scandinavia	2012 – 2016 female and male adults, muscle	µg/kg lw	830	Yuan *et al.* (2019)
Starling *Sturnus vulgaris*	Scandinavia	2012 – 2015, female and male fledglings, muscle	µg/kg lw	310	Yuan *et al.* (2019)
Common Kestrel *Falco tinnunculus*	Scandinavia	2014, egg	µg/kg lw	85	Yuan *et al.* (2019)
Tawny Owl *Strix aluco*	Scandinavia	2014, egg	µg/kg lw	87	Yuan *et al.* (2019)
Eagle Owl *Bubo bubo*	Scandinavia	2013 – 2017, female and male adults, muscle	µg/kg lw	720	Yuan *et al.* (2019)
Marsh Harrier *Circus aeruginosus*	Scandinavia	2012 – 2015 female and male adults, muscle	µg/kg lw	180	Yuan *et al.* (2019)

Sample	Location	Comment	Units	Level	Reference
Golden Eagle *Aquila chrysaetos*	Scandinavia	2012 – 2016 female and male adults, muscle	µg/kg lw	360	Yuan *et al.* (2019)
Peregrine Falcon *Falco peregrinus*	Scandinavia	2012 – 2016 female and male adults, muscle	µg/kg lw	410	Yuan *et al.* (2019)
Salmon	Southern Germany	2014 - 2017, 122 farmed and 11 wild salmon samples	µg/kg ww	1.1 - 79	Krätschmer *et al.* (2019)
Pond Loach *Misgurnus anguillicaudatus*	Paddy fields in the Yangtze River Delta, China	Median (min-max)	µg/kg lw	2 500 (1 400 – 2 600)	Du *et al.* (2018)/Zhou *et al.* (2019)
			µg/kg dw	270 (170 – 430)	
Rice Field Eel *Monopterus albus*	Paddy fields in the Yangtze River Delta, China	Median (min-max)	µg/kg lw	2 600 (820 – 3 700)	Du *et al.* (2018)/Zhou *et al.* (2019)
			µg/kg dw	140 (50 – 270)	
Red-backed Rat Snake *Elaphe rufodorsata*	Paddy fields in the Yangtze River Delta, China	Median (min-max)	µg/kg lw	3 800 (2 100 – 7 900)	Du *et al.* (2018)/Zhou *et al.* (2019)
			µg/kg dw	170 (100 – 330)	
Red-banded Snake *Dinodon rufozonatum*	Paddy fields in the Yangtze River Delta, China	Median (min-max)	µg/kg lw	13 000	Du *et al.* (2018)/Zhou *et al.* (2019)
			µg/kg dw	570	
Short-tailed Mamushi *Gloydius brevicaudus*	Paddy fields in the Yangtze River Delta, China	Median (min-max)	µg/kg lw	17 000 (7 400 – 19 000)	Du *et al.* (2018)/Zhou *et al.* (2019)
			µg/kg dw	990 (450 – 1 300)	

Sample	Location	Comment	Units	Level	Reference
Yellow Weasel *Mustela sibirica*	Paddy fields in the Yangtze River Delta, China	Median (min-max)	µg/kg lw	12 000 (6 700 – 33 000)	Du *et al.* (2018)/Zhou *et al.* (2019)
			µg/kg dw	990 (640 – 2 900)	
Peregrine Falcon *Falco peregrinus*	Paddy fields in the Yangtze River Delta, China	Median (min-max)	µg/kg lw	2 100 (1 300 – 29 000)	Du *et al.* (2018)/Zhou *et al.* (2019)
			µg/kg dw	260 (190 – 4 700)	
Collared Scops-owl *Otus lettia*	Paddy fields in the Yangtze River Delta, China	Median (min-max)	µg/kg lw	270 (96 – 440)	Du *et al.* (2018)/Zhou *et al.* (2019)
			µg/kg dw	74 (39 – 110)	
Common Cuckoo *Cuculus canorus*	Paddy fields in the Yangtze River Delta, China	Median (min-max)	µg/kg lw	200 (<170 – 1 400)	Du *et al.* (2018)/Zhou *et al.* (2019)
			µg/kg dw	25 (<12 – 92)	
Fish (no further information provided)	Bohai Bay, China	Range	µg/kg dw	42.1 – 5 307	Xia *et al.* (2016)
Polychaetes	Inner Oslofjord	3 pooled samples (whole individuals)	µg/kg ww	Average: 12	Ruus *et al*. (2018)
Blue Mussel *Mytilus edulis*	Inner Oslofjord	3 pooled samples (soft tissue)	µg/kg ww	Average: 10	Ruus *et al*. (2018)
Krill *Euphausiacea*	Inner Oslofjord	3 pooled samples (whole individuals)	µg/kg ww	60	Ruus *et al*. (2018)
Prawn *Pandalus borealis*	Inner Oslofjord	3 pooled samples (tail soft tissue)	µg/kg ww	2	Ruus *et al*. (2018)

Sample	Location	Comment	Units	Level	Reference
Herring *Clupea harengus*	Inner Oslofjord	3 pooled samples (muscle)	µg/kg ww	Average: 17	Ruus *et al*. (2018)
Atlantic Cod *Gadus morhua*	Inner Oslofjord	Liver (detected in all 15 samples)	µg/kg ww	Arithmetic mean 216 (range: 51-1050)	Ruus *et al*. (2018)
Herring Gull *Larus argentatus*	Inner Oslofjord	Blood (detected in all 15 samples)	µg/kg ww	Arithmetic mean 28.23 (range: 8.2-76)	Ruus *et al*. (2018)
	Outer Oslofjord	Blood (detected in all 15 samples)		Arithmetic mean 38.87 (range: 5.8-200)	Ruus *et al*. (2018)
	Inner Oslofjord	Egg (detected in all 15 samples)		Arithmetic mean 29.14 (range: 6.1-68)	Ruus *et al*. (2018)
	Outer Oslofjord	Egg (detected in all 15 samples)		Arithmetic mean 69.58 (range: 3.1-630)	Ruus *et al*. (2018)
Chinese Pond Heron A*rdeola bacchus*	Paddy fields, Yangtze River Delta	Muscle (n=3)	ng/g lw	830, 5 000, 9 300	Zhou et al. (2016)
Peregrine Falcon *Falco peregrinus*	Paddy fields, Yangtze River Delta	Muscle (n=3)		8 000, 130 000, 59 000	Zhou *et al.* (2016)
Short-tailed mamushi snake *Gloydius brevicaudus*	Paddy fields, Yangtze River Delta	Muscle (n=3)		340 000, 220 000, 200 000	Zhou *et al.* (2016)
Asiatic toad *Bufo gargarizans*	Paddy fields, Yangtze River Delta	Pooled muscle (n=8)		970 000	Zhou *et al.* (2016)

Sample	Location	Comment	Units	Level	Reference
Dark-spotted frog *Pelophylax nigromaculatus*	Paddy fields, Yangtze River Delta	Pooled muscle (n=5)		n.d.	Zhou *et al.* (2016)
Rice field eel *Monopterus albus*	Paddy fields, Yangtze River Delta	Pooled muscle (n=5)		7 000	Zhou *et al.* (2016)
Black-spotted frog *Pelophylax nigromaculatus*	Paddy fields, Yangtze River Delta	Pooled liver - female (n=12)	ng/g ww	Mean 69 (range: 190-910)	Du *et al.* (2019)
Black-spotted frog *Pelophylax nigromaculatus*	Paddy fields, Yangtze River Delta	Pooled liver - male (n=12)		Mean 68 (range: 5.5-180)	Du *et al.* (2019)
Black-spotted frog *Pelophylax nigromaculatus*	Paddy fields, Yangtze River Delta	Pooled egg (n=12)		Mean 16 (range: < LOQ - 52)	Du *et al.* (2019)
Black-spotted frog *Pelophylax nigromaculatus*	Paddy fields, Yangtze River Delta	Pooled muscle - female (n=3)		Mean 5 (range: 2 - 8)	Du *et al.* (2019)
Black-spotted frog *Pelophylax nigromaculatus*	Paddy fields, Yangtze River Delta	Pooled muscle - male (n=3)		Range: 25 - 50	Du *et al.* (2019)
Short-tailed mamushi snake *Gloydius brevicaudus*	Paddy fields, Yangtze River Delta	Pooled liver (n=7)	ng/g lw	mean ± sd (min-max) 1 800 ± 1 800 (<LOQ-5 100)	Du *et al.* (2020)

Sample	Location	Comment	Units	Level	Reference
Short-tailed mamushi snake *Gloydius brevicaudus*	Paddy fields, Yangtze River Delta	Pooled muscle (n=7)		mean ± sd (min-max) 14 000 ± 5 700 (7400 - 220 000)	Du *et al.* (2020)
Short-tailed mamushi snake *Gloydius brevicaudus*	Paddy fields, Yangtze River Delta	Pooled adipose (n=7)		mean ± sd (min-max) 170 ± 110 (44-290)	Du *et al.* (2020)
Red-backed rat snake *Elaphe rufodorsata*	Paddy fields, Yangtze River Delta	Pooled liver (n=9)		mean ± sd (min-max) 1 500 ± 970 (<LOQ - 3 500)	Du *et al.* (2020)
Red-backed rat snake *Elaphe rufodorsata*	Paddy fields, Yangtze River Delta	Pooled muscle (n=9)		mean ± sd (min-max) 5 500 ± 3 500 (3100 - 11 000)	Du *et al.* (2020)
Red-backed rat snake *Elaphe rufodorsata*	Paddy fields, Yangtze River Delta	Pooled adipose (n=9)		mean ± sd (min-max) 230 ± 420 (<LOQ-1 300)	Du *et al.* (2020)
Snake-head fish *Channa argus*	Dianshan Lake, Yangtze River Delta	Whole muscle (n=1)	ng/g lw	500	Zhou *et al.* (2019)
Bigmouth Grenadier Anchovy *Coilia ectenes*	Dianshan Lake, Yangtze River Delta	Pooled Muscle (n=40)		mean (min-max) 360 (270-440)	Zhou *et al.* (2019)

Sample	Location	Comment	Units	Level	Reference
Yellow catfish *Pelteobagrus fulvidraco*	Dianshan Lake, Yangtze River Delta	Whole muscle (n=1)		mean (min-max) 1 800 (760-2 800)	Zhou *et al.* (2019)
Grass carp *Ctenopharyngodon idella*	Dianshan Lake, Yangtze River Delta	Whole muscle (n=1)		340	Zhou *et al.* (2019)
Crucian carp *Carassius auratus*	Dianshan Lake, Yangtze River Delta	Whole muscle (n=1)		1 200	Zhou *et al.* (2019)
Predatory carp *Erythroculter ilishaeformis*	Dianshan Lake, Yangtze River Delta	Whole muscle (n=2)		mean (min-max) 1 900 (610-3 100)	Zhou *et al.* (2019)
Common carp *Cyprinius carpio*	Dianshan Lake, Yangtze River Delta	Whole muscle (n=1)		2 000	Zhou *et al.* (2019)
Freshwater snail *Bellamya aeruginosa*	Dianshan Lake, Yangtze River Delta	Pooled soft tissue (n=150)		mean (min-max) 3 000 (210-5 500)	Zhou *et al.* (2019)
Freshwater mussel/clam *Corbicula aurea Heude*	Dianshan Lake, Yangtze River Delta	Pooled soft tissue (n=100)		mean (min-max) 1 500 (770-2 200)	Zhou *et al.* (2019)
Chinese pond heron *Ardeola bacchus*	Paddy fields, Yangtze River Deltav	Pectoral muscle (n=5)		mean (min-max) 1 500 (290-4 600)	Zhou *et al.* (2019)

Sample	Location	Comment	Units	Level	Reference
Chicken Egg *Gallus gallus domesticus*	Paddy fields, Yangtze River Delta	Egg (n=1)		370	Zhou *et al.* (2019)
Duck Egg *Anas platyrhynchos*	Paddy fields, Yangtze River Delta	Egg (n=1)		120	Zhou *et al.* (2019)
Mantis *Tenodera sinensls*	Longtang Town, Guangdong Province	Whole body pooled (n=28)	ng/g lw	mean (min-max) 5100 (1 500-7 700)	Liu *et al.* (2020)
Dragonfly larvae (ditch)	Longtang Town, Guangdong Province	Whole body pooled (n=80)		mean (min-max) 1 100 (950-3 200)	Liu *et al.* (2020)
Dragonfly larvae (pond)	Longtang Town, Guangdong Province	Whole body pooled (n=250)		mean (min-max) 7 500 (2 000-19 000)	Liu *et al.* (2020)
Dragonfly 1 *Aeshnidae rambur*	Longtang Town, Guangdong Province	Whole body pooled (n=65)		mean (min-max) 5 500 (3 600-8 800)	Liu *et al.* (2020)
Dragonfly 2 *Libellilidae rambur*	Longtang Town, Guangdong Province	Whole body pooled (n=100)		mean (min-max) 19 000 (14 000-27 000)	Liu *et al.* (2020)
Grasshopper larvae *Oxya chinensis*	Longtang Town, Guangdong Province	Whole body pooled (n=95)		mean (min-max) 6 000 (4 000-6 600)	Liu *et al.* (2020)

Sample	Location	Comment	Units	Level	Reference
Grasshopper *Oxya chinensis*	Longtang Town, Guangdong Province	Whole body pooled (n=78)		mean (min-max) 6 500 (6 000-8 400)	Liu *et al.* (2020)
Cricket *Gryllulus chinensis*	Longtang Town, Guangdong Province	Whole body pooled (n=55)		mean (min-max) 3 600 (1 600-4 600)	Liu *et al.* (2020)
Mole cricket *Grylltopia orientalis*	Longtang Town, Guangdong Province	Whole body pooled (n=63)		mean (min-max) 3 200 (2 600-5 400)	Liu *et al.* (2020)
Beetle A*nomola corpulenta*	Longtang Town, Guangdong Province	Whole body pooled (n=63)		mean (min-max) 990 (110-1 100)	Liu *et al.* (2020)
Long-tailed shrike *Lanius schach*	Longtang Town, Guangdong Province	Muscle (n=2)		mean (min-max) 2 000, 3 000	Liu *et al.* (2020)
Eurasian blackbird *Turdus merula*	Longtang Town, Guangdong Province	Muscle (n=1)		mean (min-max) 13 000	Liu *et al.* (2020)
Oriental magpie robin *Copsychus saularis*	Longtang Town, Guangdong Province	Muscle (n=3)		mean (min-max) 18 000 (10 000-33 000)	Liu *et al.* (2020)
Oriental garden lizard *Calotes versicolor*	Longtang Town, Guangdong Province	Muscle (n=9)		mean (min-max) 9 100 (5 400-21 000)	Liu *et al.* (2020)

Sample	Location	Comment	Units	Level	Reference
Asian painted frog *Kaloula pulchra*	Longtang Town, Guangdong Province	Muscle (n=9)		mean (min-max) 9 300 (4 600-17 000)	Liu *et al.* (2020)
Black spectacled toad *Duttaphyrynus elanostictus*	Longtang Town, Guangdong Province	Muscle (n=6)		mean (min-max) 7 200 (5 300-11 000)	Liu *et al.* (2020)
Tadpole frog and toad	Longtang Town, Guangdong Province	Whole body pooled (n=60)		mean (min-max) 20 000 (19 000-22 000)	Liu *et al.* (2020)
Grass Leaves *Gramineae*	Longtang Town, Guangdong Province	n=3	ng/g dw	mean (min-max) 450 (430-600)	Liu *et al.* (2020)
Guava Leaves *Psidium guajava*	Longtang Town, Guangdong Province	n=3		mean (min-max) 420 (380-650)	Liu *et al.* (2020)
Soil (corn field and paddy fields)	Longtang Town, Guangdong Province	n=6		mean (min-max) 220 (57-390)	Liu *et al.* (2020)
Common reed *Phragmites australis*	Constructed wetland eco-system, Beijing Olympic Forest Park	Emergent plant	ng/g dw	235-435	Wang *et al.* (2021)

Sample	Location	Comment	Units	Level	Reference
Common reed *Phragmites australis* Manchurian wild rice *Zizania latifola* *Acorus calamus Linn.* Soft-stem bulrush *Scirpus validus* *Lythrum salicaria Linn.* Pygmy water lily *Nymphaea tetragona* Common duckweed *Lemna minor* Green algae *Enteromorpha prolifera*, O.F.Müller Water-shield *Brasenia schreberi,* (J.F.Gmel. Water thyme *Hydrilla verticillata* *Vallisneria natans* (Lour.) Hara	Constructed wetland eco-system, Beijing Olympic Forest Park	Emergent, Submerged and Floating plant	ng/g dw	mean ± sd (min-max) 289 ± 148 (21 - 785)	Wang *et al.* (2021)

Sample	Location	Comment	Units	Level	Reference
Southern Hemisphere Humpback Whale *Megaptera novaeangliae*	Western and Eastern Australian Coast	Blubber samples (n=9 individuals; 2 g)	ng	> 33 ng (absolute mass)	Casa *et al.* (2019)
Broad-banded Cardinalfish *Apogon fasciatus*	South China Sea	Pool	ng/g lw	3800	Zeng *et al.* (2017)
Chinese gizzard shad *Clupanodon thrissa*	South China Sea	Pool (n=13)		mean ± sd 1960 ± 677	Zeng *et al.* (2017)
Large-scale tonguesole *Cynoglossus arel*	South China Sea	Pool		810	Zeng *et al.* (2017)
Goatee croaker *Dendrophysa russelii*	South China Sea	Pool		2 090	Zeng *et al.* (2017)
Crimson sea-bream *Evynnis cardinali*	South China Sea	Pool		1 000	Zeng *et al.* (2017)
Japanese flathead *Inegocia japonica*	South China Sea	Pool		2 590	Zeng *et al.* (2017)
Large-scale croaker *Johnius heterolepis*	South China Sea	Pool (n=4)		mean ± sd 1 660 ± 561	Zeng *et al.* (2017)
Shortnose ponyfish *Leiognathus brevirostris*	South China Sea	Pool (n=6)		mean ± sd 1 540 ± 630	Zeng *et al.* (2017)

Sample	Location	Comment	Units	Level	Reference
Red big-eye *Priacanthus macracanthus*	South China Sea	Pool		1 230	Zeng *et al.* (2017)
Silver croakerv *Pennahia argentata*	South China Sea	Pool		1 260	Zeng *et al.* (2017)
Black-spotted threadfin *Polydactylus sextarius*	South China Sea	Pool		1 470	Zeng *et al.* (2017)
Bartail flathead *Platycephalus indicus*	South China Sea	Pool		2 370	Zeng *et al.* (2017)
Richard's dragonet *Repomucenus richardsonii*	South China Sea	Pool		1 320	Zeng *et al.* (2017)
White-spotted spinefoot *Signaus canaliculatus*	South China Sea	Pool (n=7)		mean ± sd 2 040 ± 1 320	Zeng *et al.* (2017)
Ovate sole *Solea ovata*	South China Sea	Pool		1 320	Zeng *et al.* (2017)
Redy goby fish *Trypauchen vagina*	South China Sea	Pool		1 480	Zeng *et al.* (2017)
Squillid mantis shrimp *Harpiosquilla harpax*	South China Sea	Pool (n=4)		mean ± sd 975 ± 330	Zeng *et al.* (2017)
Jinga shrimp *Metapenaeus affinis*	South China Sea	Pool (n=5)		mean ± sd 503 ± 272	Zeng *et al.* (2017)

Sample	Location	Comment	Units	Level	Reference
Small-eyed squillid mantis shrimp *Miyakea nepa*	South China Sea	Pool		471	Zeng *et al.* (2017)
Greasyback shrimp *Meapenaeus ensis*	South China Sea	Pool		525	Zeng *et al.* (2017)
Three-spotted crab *Portunus sanguinolentus*	South China Sea	Pool (n=5)		mean ± sd 496 ± 151	Zeng *et al.* (2017)
Blue swimmer crab *Portunus pelagicus*	South China Sea	Pool		855	Zeng *et al.* (2017)
Swimming crab *Portunus trituberculatus*	South China Sea	Pool		392	Zeng *et al.* (2017)
Rusty ark *Anadara ferruginea*	South China Sea	Pool		596	Zeng *et al.* (2017)
Common frog shell *Bufonaria rana*	South China Sea	Pool		754	Zeng *et al.* (2017)
Rare-spined murex *Murex trapa*	South China Sea	Pool		563	Zeng *et al.* (2017)
Turreted sea snail *Turritella bacillum*	South China Sea	Pool		515	Zeng *et al.* (2017)

Table 20: Summary of levels of "MCCPs" in air

Location	Comment	Units	Concentration	Reference
Dongjiang River, China	Air samples	µg/sampler	4.1	Wang *et al.* (2013)
	Atmospheric depositions (wet and dry) at 11 sites	µg/(m^2d)	5.3	
Shergyla Mountain and Lhasa (Tibetan Plateau)	Air samples	pg/m^3	50 – 690 800 – 6700	Wu *et al.* (2019)
Georgia King Island, Fildes Peninsula of Antarctica (Great Wall Station)	Air samples	pg/m^3	3.7 – 5.2 (average: 4.5)	Ma *et al.* (2014)
King George Island, Fildes Peninsula of Antarctica (Great Wall Station)	monthly air samples: 2014	pg/m^3	2.47 (annual average)	Jiang *et al.* (2021)
King George Island, Fildes Peninsula of Antarctica (Great Wall Station)	monthly air samples: 2015	pg/m^3	5.54 (annual average)	Jiang *et al.* (2021
King George Island, Fildes Peninsula of Antarctica (Great Wall Station)	monthly air samples: 2016	pg/m^3	6.46 (annual average)	Jiang *et al.* (2021
King George Island, Fildes Peninsula of Antarctica (Great Wall Station)	monthly air samples: 2017	pg/m^3	15.1 (annual average)	Jiang *et al.* (2021
King George Island, Fildes Peninsula of Antarctica (Great Wall Station)	monthly air samples: 2018	pg/m^3	10.2 (annual average)	Jiang *et al.* (2021
India	Air samples (average)	ng/m^3	3.62	Chaemfa *et al.* (2014)
Pakistan	Air samples (average)	ng/m^3	4.21	Chaemfa *et al.* (2014)

Location	Comment	Units	Concentration	Reference
Shenzhen, Guangzhou Province, China	Air samples (28 samples collected over 4 seasons, September 2013 to August 2014)	ng/m^3	0.70–12.2	Li *et al.* (2018b)
Zeppelin (Svalbard, Norway)	Air samples (2013) weekly	pg/m3	3 – 42 (monthly averages) Annual mean: 23	Bohlin-Nizzetto *et al.* (2014)
Zeppelin (Svalbard, Norway)	Air samples (2014) weekly	pg/m3	<3 – 224 (monthly averages) Annual mean: 31	Bohlin-Nizzetto *et al.* (2015)
Zeppelin (Svalbard, Norway)	Air samples (2015) weekly	pg/m3	20 – 595 (monthly averages) Annual mean: 130	Bohlin-Nizzetto & Aas (2016
Zeppelin (Svalbard, Norway)	Air samples (2016) weekly	pg/m3	10 – 380 (monthly averages) Annual mean: 70	Bohlin-Nizzetto *et al.* (2017)
Zeppelin (Svalbard, Norway)	Air samples (2017) weekly	pg/m3	10 – 380 (monthly averages) Annual mean: 70	Bohlin-Nizzetto *et al.* (2018)
Zeppelin (Svalbard, Norway)	Air samples (2018) weekly	pg/m3	10 – 380 (monthly averages) Annual mean: 70	Bohlin-Nizzetto *et al.* (2019)
Zeppelin (Svalbard, Norway)	Air samples (2019) weekly	pg/m^3	<44 to 3 900 (mean: 270)	Bohlin-Nizzetto *et al.* (2020)

Location	Comment	Units	Concentration	Reference
Birkenes (Southern Norway)	Air samples (2017) Monthly	pg/m^3	15 – 772 (monthly samples) 160 (annual mean)	Bohlin-Nizzetto *et al.* (2018)
Birkenes (Southern Norway)	Air samples (2018) Monthly	pg/m^3	100 – 3754 (monthly samples) 960 (annual mean)	Bohlin-Nizzetto *et al.* (2019)
Birkenes (Norway)	Air samples (2019) Monthly	pg/m^3	<95 to 1 500 (mean: 330)	Bohlin-Nizzetto *et al.* (2020)
Aspvreten and Råö, Sweden	Air (2012 – 2017) “four months evenly distributed throughout the year”	ng/m^3	0.011 - 0.91 0.006 - 0.024	IVL, 2018
Aspvreten and Råö, Sweden	Air (deposit) 2012 – 2017 Annual average, based on 4 measurements / year	ng/m2	4.3 to 1150 5.5 to 270	IVL, 2018
Chinese Bohai Sea	20 gaseous phase samples; 20 particulates samples	pg/m^3	460 to 1 900 560 to 4 900	Ma *et al.* (2018)