# Screening Assessment for the Challenge

# Octamethylcyclotetrasiloxane
# (D4)

## Chemical Abstracts Service Registry Number
## 556-67-2

**Environment Canada**
**Health Canada**

**November 2008**

# Synopsis

Pursuant to section 74 of the *Canadian Environmental Protection Act, 1999* (CEPA 1999), the Ministers of the Environment and of Health have conducted a screening assessment on octamethylcyclotetrasiloxane (D4), Chemical Abstracts Service Registry Number 556-67-2. During the categorization process, this substance was identified as a high priority for screening assessment and included in the Ministerial Challenge because it had been considered to pose an intermediate potential for exposure to individuals in Canada and has been classified by another agency on the basis of reproductive toxicity. Further, it had initially been found to meet the ecological categorization criteria for persistence, bioaccumulation potential and inherent toxicity (PBiT) to non-human organisms and it is known to be in commerce in Canada.

Octamethylcyclotetrasiloxane, or D4, is an industrial chemical which was not manufactured by any company in Canada in 2006 in a quantity above the reporting threshold of 100 kg, but which was imported into the country in 2006 at a total quantity between 1 000 000 and 10 000 000 kg as an essentially pure substance, in mixtures with other cyclic siloxanes, as a residual in silicone polymers, and in finished consumer products.

The principal sources of release of D4 to the environment are industrial processes in which it is reacted to form silicone polymers, from blending, formulation and packaging operations. It is also released from the use and disposal of personal care products. Air, wastewater and agricultural soil are the principal receiving environmental media for D4 based on its physical-chemical properties and its use patterns.

In air, D4 is persistent with calculated atmospheric half-lives of more than 5 days. D4 has the potential to be transported over long-distances in the atmosphere. However, it has a low potential to be deposited in water or soil in remote regions. The hydrolysis half-lives for D4 under Canadian water conditions (pH 6-9, temperature 5-25°C) are estimated to range from hours to 45 days, indicating the substance is not persistent in water. The final hydrolysis product dimethylsilanediol is expected to biodegrade quite slowly. D4 degradation in sediment appears to be much slower with half-lives of 49 to 588 days estimated under realistic Canadian sediment conditions (temperature of 5-25°C), indicating the substance may be persistent in sediment. D4 is not considered persistent in soil, based on evidence of clay-catalysed degradation, with dimethylsilanediol being the stable hydrolysis product. Therefore, D4 has been determined to meet the persistence criterion as set out in the *Persistence and Bioaccumulation Regulations.*

The empirical bioconcentration factor and modelled bioaccumulation factor are both above 5000, indicating D4 may have a high potential to accumulate in aquatic organisms. However, data from a biomagnification study in fish and a biota-sediment accumulation study in invertebrates suggest that the bioaccumulation potential of D4 may be lower, possibly due to reduced bioavailability. Therefore, while D4 has the potential to accumulate in biota, it is not possible to conclude at this time that D4 meets the criterion for bioaccumulation as set out in the *Persistence and Bioaccumulation Regulations* based on consideration of the conflicting evidence from laboratory studies and predictive models.

Adverse effects from exposure to D4 in sediment-dwelling organisms were observed at concentrations above 44 mg/kg. The experimental toxicity data show that the substance can also cause long-term toxicity to sensitive pelagic aquatic organisms at relatively low concentrations (below its water solubility limit of 0.056 mg/L ). Risk quotients derived from exposure scenarios involving discharges of D4 from both consumer use and industrial operations, show a total of 249 sites (~23.4%) evaluated across Canada have predicted environmental concentrations in water higher than predicted no-effect concentrations for aquatic organisms. Considering D4's potential to bioaccumulate in biota and its high toxicity to sensitive aquatic organisms, long-term environmental exposure to D4 may cause adverse effects to aquatic organisms in certain Canadian environments. Based on this evidence, it is concluded that D4 has the potential to cause ecological harm.

Based principally on the weight of evidence-based assessments of the European Commission and the Danish EPA, an important effect of D4 exposure is impaired fertility. However, the Danish EPA also identified the liver as a target organ for D4 exposures. The critical effect level for repeated-dose toxicity via inhalation was based not only on increased liver weights, but also on effects observed in other organs (adrenals, thymus, lungs) in a three-month rat inhalation study. Comparison of the critical effect level for repeated dose effects via inhalation and the conservative upper-bounding exposure estimate via inhalation for D4 results in an adequate margin of exposure. The critical effect level for repeated-dose toxicity via the oral route was based on decreased serum estradiol in 7-day mouse studies and decreased body-weights and relative liver weights in fetuses in 8-day rat studies (D4 administered to pregnant females). Comparison of the critical effect level for repeated dose effects via the oral route and the upper-bounding estimate of daily intake of D4 by the general population in Canada, results in an adequate margin of exposure.

Based on an independent review of a refined exposure assessment for personal care products, an adequate margin of exposure was derived by comparison of the critical effect level for repeated dose effects via the oral route and a conservative upper-bounding estimate of daily intake of D4 via use of personal care products.

Based on the available information on its potential to cause ecological harm, it is concluded that D4 is entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity.

Based on the available information on its potential to cause harm to human health, it is concluded that D4 is not entering the environment in a quantity or concentration or under conditions that constitute or may constitute a danger in Canada to human life or health.

This substance will be included in the upcoming *Domestic Substances List* inventory update initiative. In addition and where relevant, research and monitoring will support verification of assumptions used during the screening assessment and, where appropriate, the performance of potential control measures identified during the risk management phase.

Based on the information available, it is concluded that D4 meets one or more of the criteria set out in section 64 of the *Canadian Environmental Protection Act, 1999*.

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# Introduction

The *Canadian Environmental Protection Act, 1999* (CEPA 1999) (Canada 1999) requires the Minister of the Environment and the Minister of Health to conduct screening assessments of substances that have met the categorization criteria set out in the Act to determine whether these substances present or may present a risk to the environment or human health. Based on the results of a screening assessment, the Ministers can propose to take no further action with respect to the substance, to add the substance to the Priority Substances List (PSL) for further assessment, or to recommend that the substance be added to the List of Toxic Substances in Schedule 1 of the Act and, where applicable, the implementation of virtual elimination.

Based on the information obtained through the categorization process, the Ministers identified a number of substances as high priorities for action. These include substances that

- met all of the ecological categorization criteria, including persistence (P), bioaccumulation potential (B) and inherent toxicity to aquatic organisms (iT), and were believed to be in commerce in Canada; and/or
- met the categorization criteria for greatest potential for exposure (GPE) or presented an intermediate potential for exposure (IPE), and had been identified as posing a high hazard to human health based on classifications by other national or international agencies for carcinogenicity, genotoxicity, developmental toxicity or reproductive toxicity.

The Ministers therefore published a notice of intent in the *Canada Gazette*, Part I, on December 9, 2006 (Canada 2006), that challenged industry and other interested stakeholders to submit, within specified timelines, specific information that may be used to inform risk assessment, and to develop and benchmark best practices for the risk management and product stewardship of those substances identified as high priorities.

The substance Cyclotetrasiloxane, octamethyl-, also known as D4, was identified as a high priority for assessment of human health risk because it was considered to present an IPE and had been classified by other agencies on the basis of reproductive toxicity. It was also identified as a high priority for assessment of ecological risk as it was found to be persistent (P), bioaccumulative (B) and inherently toxic (iT) to aquatic organisms and is known to be in commerce in Canada. The Challenge for this substance was published in the *Canada Gazette* on May 12, 2007 (Canada 2007). A substance profile was released at the same time. The substance profile presented the technical information available prior to December 2005 that formed the basis for categorization of this substance. As a result of the Challenge, more than 100 submissions of information were received for this substance pertaining to its physical and chemical properties, bioaccumulation potential, persistence, ecotoxicology, quantity in commerce, and so on.

Under CEPA 1999, screening assessments focus on information critical to determining whether a substance meets the criteria for defining a chemical as toxic as set out in section 64 of the Act, where

> "64. […] a substance is toxic if it is entering or may enter the environment in a quantity or concentration or under conditions that
>
> (*a*) have or may have an immediate or long-term harmful effect on the environment or its biological diversity;
>
> (*b*) constitute or may constitute a danger to the environment on which life depends; or
>
> (*c*) constitute or may constitute a danger in Canada to human life or health."

Screening assessments examine scientific information and develop conclusions by incorporating a weight-of-evidence approach and precaution.

This screening assessment includes consideration of information on chemical properties, hazards, uses and exposure, including the additional information submitted under the Challenge. Data relevant to the screening assessment of this substance were identified in original literature, review and assessment documents, stakeholder research reports and from recent literature searches, up to August 2008 for both human health and ecological sections of the document. Key studies were critically evaluated; modelling results may have been used to reach conclusions. When available and relevant, information presented in hazard assessments from other jurisdictions was considered. The screening assessment does not represent an exhaustive or critical review of all available data. Rather, it presents the most critical studies and lines of evidence pertinent to the conclusion.

Evaluation of risk to human health involves consideration of data relevant to estimation of exposure (non-occupational) of the general population, as well as information on health hazards (based principally on the weight-of-evidence assessments of other agencies that were used for prioritization of the substance). Decisions for human health are based on the nature of the critical effect and/or margins between conservative effect levels and estimates of exposure, taking into account confidence in the completeness of the identified databases on both exposure and effects, within a screening context. The screening assessment does not represent an exhaustive or critical review of all available data. Rather, it presents a summary of the critical information upon which the conclusion is based.

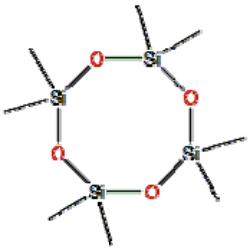
This screening assessment was prepared by staff in the Existing Substances Programs at Health Canada and Environment Canada and incorporates input from other programs within these departments. This assessment has undergone external written peer review/consultation. Comments on the technical portions relevant to human health were received from Toxicology Excellence for Risk Assessment (TERA). While external comments were taken into consideration, the final content and outcome of the screening risk assessment remain the responsibility of Health Canada and Environment Canada. Additionally, the draft of this screening assessment was subject to a 60-day public comment period. The critical information and considerations upon which the assessment is based are summarized below.

# Substance Identity

For the purposes of this document, Cyclotetrasiloxane, octamethyl- will be referred to as D4, an abbreviated name derived from the siloxane notation developed by General Electric (Hurd 1946).

D4 belongs to a group of cyclic volatile methyl-siloxanes (cVMS) with relatively low molecular weight (< 600) and high vapour pressure. These cVMS are volatile, low-viscosity silicone fluids consisting of $[-Si(CH_3)_2O-]_x$ structure units in a cyclic configuration. D4 consists of four of these $[-Si(CH_3)_2O-]$ structure units (x = 4) as shown in the chemical structure below (Table 1).

**Table 1. Substance identity**

| | |
|---|---|
| **Chemical Abstracts Service Registry Number (CAS RN)** | **556-67-2** |
| **Name on Domestic Substances List (DSL)** | **Cyclotetrasiloxane, octamethyl-** |
| **National Chemical Inventories (NCI) names**[1] | Cyclotetrasiloxane, 2,2,4,4,6,6,8,8-octamethyl- (TSCA); Cyclotetrasiloxane, octamethyl- (ENCS, AICS, PICCS, ASIA-PAC, NZIoC); Octamethylcyclotetrasiloxane (EINECS, ECL, PICCS); Cyclotetrasiloxane,octamethyl (PICCS) |
| **Other names** | Cyclic dimethylsiloxane tetramer; D4; Tetracyclomethicone; Siloxane, octamethylcyclotetra-; Siloxanes and Silicones, octamethylcyclotetra-; Siloxanes, octamethylcyclotetra-; 1,1,3,3,5,5,7,7-Octamethylcyclotetrasiloxane; 2,4,6,8-Octamethylcyclotetrasiloxane; OMCTS; Cyclo(octamethyl)tetrasiloxane |
| **Major chemical class or use** | Organosilicon compounds |
| **Major chemical sub-class** | Cyclic volatile methyl siloxanes (cVMS) |
| **Molecular formula** | $C_8H_{24}O_4Si_4$ |
| **Chemical structure** |  |
| **Simplified Molecular Input Line Entry System (SMILES)** | C[Si]1(C)O[Si](C)(C)O[Si](C)(C)O[Si](C)(C)O1 |
| **Molecular mass** | 296.62 g/mol |

[1] National Chemical Inventories (NCI). 2007: AICS (Australian Inventory of Chemical Substances); ASIA-PAC (Asia-Pacific Substances Lists); ECL (Korean Existing Chemicals List); EINECS (European Inventory of Existing Commercial Chemical Substances); NZIoC (New Zealand Inventory of Chemicals); PICCS (Philippine Inventory of Chemicals and Chemical Substances); and TSCA (Toxic Substances Control Act Chemical Substance Inventory).

It should be noted that D4 is also contained under another Chemical Abstracts Service Registry Number. This registry number, CAS RN 69430-24-6, refers to a mixture of dimethyl substituted cyclosiloxanes of the general structure $[\text{-Si}(CH_3)_2\text{O-}]_x$ in a cyclic configuration, where x is generally less than 8, and more commonly x is 3–7 (SEHSC 2007b). This CAS number is associated with the following names: cyclopolydimethylsiloxane, cyclopolydimethylsiloxane (DX), cyclosiloxanes di-Me, dimethylcyclopolysiloxane, polydimethyl siloxy cyclics, polydimethylcyclosiloxane, cyclomethicone and mixed cyclosiloxane. In this report it will be referred to as cyclomethicone, a term commonly used for the mixture in the cosmetics industry.

# Physical and Chemical Properties

Table 2 contains experimental and modelled physical and chemical properties of D4 that are relevant to its environmental fate.

**Table 2. Physical and chemical properties of D4**

| Property | Type | Value[1] | Temperature (°C) | Reference |
|---|---|---|---|---|
| **Melting point (ºC)** | Experimental | 17.5* | | PhysProp 2006 |
| | Modelled | 1.78 | | MPBPWIN 2000 |
| **Boiling point (ºC)** | Experimental | 175.8* | | PhysProp 2006 |
| | Modelled | 159.41 | | MPBPWIN 2000 |
| **Density ($kg/m^3$)** | Experimental | 950 | 25 | Hobson and Silberhorn 1995 |
| **Vapour pressure (Pa)** | Experimental | 140* (1.05 mm Hg) | 25 | Flaningam 1986 |
| | | 132 (0.99 mm Hg) | 25 | SEHSC 2007c |
| | Modelled | 157.3 (1.18 mm Hg) | 25 | MPBPWIN 2000 |
| **Henry's Law constant ($Pa \cdot m^3/mol$)** | Experimental | 1 220 000* (12.0 $atm \cdot m^3/mol$) | | Calculated from $K_{aw}$ value of Xu and Kropscott 2007 |
| | | 11898 (0.117 $atm \cdot m^3/mol$) | 25 | Hamelink et al. 1996 |
| | | 60060 (0.593 $atm \cdot m^3/mol$) | 28 | Kochetkov et al. 2001 |
| | | 57558 (0.568 $atm \cdot m^3/mol$) | 28 | Kochetkov et al. 2001 |
| | Modelled | 9119.3 (0.09 $atm \cdot m^3/mol$) | 25 | HENRYWIN 2000 |
| **Log $K_{aw}$ (Air-water partition coefficient) (dimensionless)** | Experimental | 2.69* | 21.7 | Xu and Kropscott 2007 |
| **Log $K_{ow}$ (Octanol-water partition coefficient) (dimensionless)** | Experimental | 6.49* | 25.1 | Kozerski and Shawl 2007 |
| | | 5.1 | | TSCATS 2006 |
| | | 4.45 | | Bruggeman et al. 1984 |
| | Modelled | 5.09 | | KOWWIN 2000 |
| **Log $K_{oc}$ (Organic carbon-water partition coefficient) (dimensionless)** | Experimental | 4.22* | 24 | Miller 2007 |
| | Modelled | 4.25 | | PCKOCWIN 2000 |
| **Water solubility (mg/L)** | Experimental | 0.0562* | 23 | Varaprath et al. 1996 |
| | | 0.074 (freshwater) | | Hobson and Silberhorn 1995 |
| | | 0.033 (saltwater) | | Hobson and Silberhorn 1995 |
| | Modelled | 0.05 | 25 | WSKOWWIN 2000 |
| | Experimental | 4.34* | 25 | Xu 2006 |

| Property | Type | Value[1] | Temperature (°C) | Reference |
|---|---|---|---|---|
| | Modelled | 4.42 | | Calculated from modelled Log $K_{ow}$-Log $K_{aw}$ |

[1] If different, values and units in parentheses represent the original values as reported by the authors or as estimated by the models.
* Values used in modelling for this screening assessment.

A recent experimental log $K_{ow}$ for D4 (99.77% purity) at 25.1˚C was determined by using the slow stir method following OECD Draft Guideline 123 (Kozerski and Shawl 2007). The measurement of $K_{ow}$ was carried out in triplicate with one blank control. Two-litre borosilicate glass vessels were used in performing the equilibrium and were charged with 1.6 L high-purity water followed by adding 0.11 L of 1-octanol carefully to minimize droplet formation. The test was initiated by adding ~0.9 mL of D4 spiking solution (56.53 mg D4/g) in 1-octanol to the test vessel. The temperature was maintained at between 24.8 and 26.0ºC (averaged 25.1ºC) during the study, except when temperature temporarily reached 26.3ºC eight hours after test initiation. It was concluded that equilibrium was achieved 24 hours after test initiation. The weighted average $K_{ow}$ was calculated to be 6.49. A headspace of ~0.3 L (15% total volume) was present in the test vessels, indicating that D4 may have volatized into the headspace from the water phase (high vapour pressure, low water solubility). However, a flask mass balance check suggested that the total vaporized D4 was less than 2%. Therefore, the study is considered acceptable and the log $K_{ow}$ of 6.49 will be used for this screening assessment report.

Other log $K_{ow}$ values of 4.45 and 5.1 were reported by TSCATS (TSCATS 2006) and Bruggeman et al. (1984). The log $K_{ow}$ value of 5.1 was obtained from a direct experimental study of the octanol-water partition coefficient of D4 using the shake flask method. The study was unpublished and the detailed test design was not available. It is apparent that precautions were taken in the study to ensure that the D4 concentration in the aqueous phase was below its water solubility. The testing system was vigorously mixed followed by equilibration to separate the two phases. It was speculated (Kozerski and Shawl 2007) that microdroplets of octanol might be present in the aqueous phase due to the mixing method used. This could lead to the underestimation of the $K_{ow}$ value. The log $K_{ow}$ value of 4.45 was determined by Bruggeman et al. (1984) using a high-performance liquid chromatography (HPLC)-retention time method. The measurement was performed on an octadecylsilyl-bonded silica column with 90:10 methanol:water as the mobile phase. Homologous series of n-alkylbenzenes with known log $K_{ow}$ values were used as reference compounds to calibrate the method. The experimental details of this study are currently unavailable.

Recent experiments on the air-water partition coefficient for D4 and D5 were conducted by Xu Kropscott (2007). The partitioning equilibrium among air, water and an organic phase (octanol) was simultaneously achieved during the experiment; the log $K_{oa}$ was calculated to be 4.37 and the log $K_{ow}$ was calculated to be 6.98 for D4. Both values are reasonably consistent with the measured experimental values reported by Xu (2006, Table 2) and Kozerski and Shawl (2007),. The study is therefore considered acceptable and the log $K_{aw}$ of 2.69 for D4 from the study will be used for this screening assessment report. A custom-made double syringe system was designed for measuring the partitioning equilibrium among the three phases. The system

consisted of two air-tight syringes with the left syringe containing ~5 mL octanol-saturated water, $^{14}$C-labelled D4 in octanol on top of the water phase, and a gas phase of ~70–80 cm$^3$. The right syringe contained a ~60–80 mL octanol-saturated water phase and a ~20–40 cm$^3$ air phase. The air phases of the two syringes were connected during the test. The equilibrium between the air and water phase was accelerated by the slow stirring of water and was reached after 20 hours. The average log $K_{aw}$ of 2.69 for D4 at 21.7ºC was thus determined based on the total D4 radioactivity in air and water. This value is in good agreement with the equilibrium of log $K_{ow}$ = log $K_{oa}$ + log $K_{aw}$. The experimental $K_{aw}$ gives a Henry's Law constant of 1 220 000 Pa•m$^3$/mol at 21.7ºC.

For D4, other modelled physical and chemical properties are in good agreement with its measured experimental data. Except for the data discussed above, the most conservative experimental data, when applicable, are used in various model predictions in this screening assessment report.

## Sources

There are no known natural sources of D4.

D4 is an industrial chemical which was not manufactured by any company in Canada in 2006 in a quantity above the reporting threshold of 100 kg, but which is imported into the country as an essentially pure substance (greater than 99% purity), in mixtures with other cyclic siloxanes, as a residual in silicone polymers, and in finished consumer products. From responses to a notice published under section 71 of CEPA 1999, it was determined that between 1 000 000 and 10 000 000 kg of D4 were imported into Canada in 2006, as raw materials or in finished products (Environment Canada 2007).

D4 is a constituent of CAS RN 69430-24-6, termed cyclomethicone in the cosmetics industry. Although cyclomethicone was not directly surveyed under CEPA section 71 by Environment Canada and Health Canada in 2007, it is evident that in some cases, responses to the notice published under section 71 of CEPA 1999 for the 2006 calendar year contained data on the quantity of D4 used or imported as CAS RN 69430-24-6 (Environment Canada 2007).

The quantity of CAS RN 69430-24-6 reported in commerce in Canada during the 1986 calendar year was 2 220 000 kg (Environment Canada 1988). In 2005, Canada was a net importer of 11 500 000 kg of all types of silicone polymers and siloxanes (Will et al. 2007).

Polydimethylsiloxane (PDMS) silicone polymers are produced from D4, and all PDMS contains residual amounts of volatile cyclosiloxanes, including D4. The lower molecular weight (and consequently lower viscosity) polymers may contain from < 0.1% to 0.5% volatile cyclosiloxanes, and higher molecular weight (and consequently higher viscosity) polymers may contain 1–3% volatile cyclosiloxanes. The proportion of the volatile cyclosiloxanes that consists of D4 is highly product-specific. Release of D4 from some applications of PDMS is expected to occur once the PDMS product is in use (SEHSC 2007a).

D4 has been identified as a high production volume (HPV) chemical by the Organisation for Economic Co-operation and Development (OECD 2007), the European Chemicals Bureau (ECB 2007), and the US Environmental Protection Agency (US EPA 2007).

In the United States, there is a trend toward the increased use of volatile methyl-siloxanes, including D4, because of their exemption from volatile organic compound (VOC) legislation in 1994 (US EPA 1994). Volatile methyl-siloxanes were used as an alternative to chlorofluorocarbons (CFCs) as a means of reducing the regulated VOC content in products (specifically, precision and electronic cleaning applications). According to information from the US EPA, the import/production of D4 in the United States was in the range of 22 500–45 000 tonnes in all reporting years from 1986 to 2002.

In Europe, D4 has been classified as R53, "may cause long-term adverse effects in the aquatic environment," and R62, "possible risk of impaired fertility" (ECB 2007). Four companies have been identified as producers/importers of D4 by the European Chemicals Bureau: Bayer AG and Wacker-Chemie GmBH of Germany, Rhone-Poulenc Chimie of France and Dow Corning Europe of Belgium (ECB 2007). The quantity of D4 used in the European Union as a site-limited intermediate and in household products during 2003–2004 is confidential information.

## Uses

The most important use, worldwide and in Canada, of high-purity D4 is as a raw material in the manufacture of silicone polymers and copolymers. All silicone polymers contain trace residual amounts of volatile cyclosiloxanes, including D4. D4 is also used in personal care products. As indicated above, D4 is also a constituent of CAS RN 69430-24-6, cyclomethicone.

Cyclomethicone is a mixture of low molecular weight volatile cyclic siloxanes, the principal ingredients of which are octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5) and dodecamethylcyclohexasiloxane (D6), in varying proportions. In Canada, the most important uses of the mixtures of low molecular weight volatile cyclic siloxanes, which may contain a high percentage of D4 or of D5, are in the preparation of personal care products, including hair and skin care products and antiperspirants (Environment Canada 2007).

Silicone polymers that contain trace amounts of D4 can be grouped as fluids, gums and resins. Uses of such polymers are described below.

Important uses of silicone fluids include as a formulation component of personal care products for hair and skin care, antiperspirants and deodorants; pharmaceuticals; processing aids such as defoamers; surfactants and mould release agents; lubricants; polishes and coatings on a range of substrates including textiles, carpeting and paper; sealants; architectural coatings; mechanical, heat transfer and dielectric fluids; and reprography (Will et al. 2007).

While it is anticipated that higher molecular weight polymers are used in most of these applications, D4 was reported for use as a defoamer (Environment Canada 2007). Defoamers are employed often at parts per million levels in a range of processing industries including pulp and

paper, food, petrochemical, petroleum, and chemical manufacture as well as water treatment. Silicones are also used as defoamers in household products such as cleaners and detergents (Will et al. 2007).

The use of silicone formulants containing D4 in certain pesticide products is regulated in Canada under the *Pest Control Products Act* (PMRA 2007).

Biomedical uses of silicone gels and fluids in Canada include medical devices, blood-handling equipment, as a blood defoaming agent, as protective barriers and lubricants and as surface treatment of wound dressings. Silicone fluids have been approved as active and non-active ingredients in pharmaceuticals in Canada (DPD 2007), the most common use being in anti-flatulence drugs.

Silicone gums are used in the production of elastomers that are used as sealants and adhesives, and in moulded silicone rubber, film and fabric coatings and encapsulation. Silicone elastomers are used in the manufacture of consumer products such as pacifiers. Silicone elastomers are also used in a large number of biomedical applications including short- and long-term implants and prostheses, catheters, contact lenses and dentures (Will et al. 2007).

Silicone resins are primarily used in specialty coatings applications, and in the production of silicone-modified polymers (Will et al. 2007). Consumers may be exposed to D4 through the use of these products and by occupying enclosed spaces where coatings, caulking, sealants and silicone rubber are used as building materials or are present in consumer products.

## Releases to the Environment

D4 is not reported as part of Environment Canada's National Pollutant Release Inventory. This substance belongs to a chemical group used in various industry and consumer applications that are associated with widespread releases.

D4 may be emitted to the environment from industrial processes in which it is reacted to form silicone polymers and co-polymers and from blending, formulation and packaging operations. All of these operations take place in Canada (Environment Canada 2007). Industrial releases of D4 may also occur when silicone polymers are used in process industries as foam control agents, as mould release agents, as lubricants, and in other applications. The releases from industrial processes are expected to be to the atmosphere and wastewater. D4 will be released during the use of personal care products such as hair and skin care products, antiperspirants and others, and these releases will be to air and wastewater. It is estimated that 92% of D4 used in personal care products enters the atmosphere (Allen et al. 1997).

Detection of D4 at sewage treatment plants, landfills and near industrial plants as well as in indoor and ambient air away from industrial activity is evidence that both point sources and disperse sources contribute to the concentration of D4 in the environment (Norden 2005; Kaj et al. 2005; personal communication, Environment Canada, Canadian Centre for Inland Waters,

2007 [unreferenced]). The application of D4-containing pesticides on crops and the disposal of sewage sludge on agricultural lands and in landfills will result in the release of D4 to environmental media. There is some evidence that D4 is a transient degradation product of PDMS in contact with soil, while the principal degradation products are silanols prior to complete mineralization (Herner et al. 2002). Thus, in addition to release of residual D4 from PDMS manufacture, there may be *de novo* synthesis of D4 occurring in landfills and agricultural lands where sewage sludge containing PDMS is spread, although the overall contribution of PDMS degradation is not considered significant under environmental conditions.

### *Mass Flow Tool*

To estimate the potential release of D4 to the environment at different stages of its life cycle, a Mass Flow Tool was used. Empirical data concerning releases of specific substances to the environment are seldom available. Therefore, for each identified type of use of the substance, the proportion and quantity of release to the different environmental media are estimated, as are the proportions of the substance chemically transformed or sent for waste disposal. Assumptions and input parameters used in making these estimates are based on information obtained from a variety of sources including responses to regulatory surveys, Statistics Canada, manufacturers' websites and technical databases. Of particular relevance are emission factors, which are generally expressed as the fraction of a substance released to the environment, particularly during its manufacture, transformation, and use associated with industrial processes. Sources of such information include emission scenario documents, often developed under the auspices of the Organisation for Economic Co-operation and Development (OECD), and default assumptions used by different international chemical regulatory agencies. It is noted that the level of uncertainty in the mass of substance and quantity released to the environment generally increases further down the life cycle.

**Table 3. Estimated releases and losses of D4 to environmental media, transformation and distribution to management processes, based on the Mass Flow Tool[1]**

| Fate | Proportion of the mass (%)[1] | Major life-cycle stage involved[2] |
|---|---|---|
| **Releases to environment:** | | |
| To soil | 0.0 | - |
| To air | 11.9 | Industrial use and consumer use |
| To sewer* | 4.9 | Production, formulation, industrial use and consumer use |
| **Chemically transformed** | 82.5 | Industrial use |
| **Transferred to waste disposal sites (e.g., landfill, incineration)** | 0.8 | Waste disposal |

* Wastewater before any form of treatment

[1] For D4, information from the following OECD emission scenario documents was used to estimate releases to the environment and distribution of the substance as summarized in this table: OECD 2004; OECD 2006. Values presented for release to environmental media do not account for possible mitigation measures that may be in place in some locations (e.g., partial removal by sewage treatment plants). Specific assumptions used in the derivation of these estimates are summarized in Environment Canada 2008a.

[2] Applicable stage(s): production, formulation, industrial use, consumer use, service life of article/product, waste disposal.

Based on the information available, about 82.5% of the quantity of D4 imported into Canada is used as a chemical intermediate by the silicone industry and is thereby considered to be chemically transformed during the manufacturing process (Table 3). For the remaining D4, the

main compartments of release are to air (11.9%) and wastewater (4.9%). Air receives the highest proportion of releases, a result of the use of consumer products such as skin creams, sun creams or polishes and also volatilization of residues in silicone polymers, especially during the first year of use. Releases to wastewater are estimated to be approximately 4.9% from point sources during on-site formulation of personal care products and from diffuse sources associated with the use of personal care products (e.g., hair care products).

## Environmental Fate

Based on its physical and chemical properties (Table 2) and the results of Level III fugacity modelling (Table 4; model input parameters are listed in Appendix 5 of this screening assessment), D4 may partition in significant quantities to any environmental medium, depending on the compartment of release.

**Table 4. Results of the Level III fugacity modelling for D4 (EQC 2003)**

| | Percentage of substance partitioning into each compartment | | | |
|---|---|---|---|---|
| **Substance released to** | **Air** | **Water** | **Soil** | **Sediment** |
| Air (100%) | 100.0 | 0.0 | 0.0 | 0.0 |
| Water (100%) | 13.6 | 72.2 | 0.0 | 14.2 |
| Soil (100%) | 88.5 | 0.0 | 11.5 | 0.0 |

Based on the available information (Table 3), the environmental release of D4 is estimated to be mainly to air (~12% of the total mass). A vapour pressure of 132–157.3 Pa and a Henry's Law constant of 1 220 000 Pa·m$^3$/mol, as well as a long half-life in air, indicate that 100% of the mass fraction released to air will remain there until it is degraded by hydroxyl radicals in air (Table 4).

When D4 is released to water it is expected to adsorb to suspended solids, such as sewage sludge and sediments, based on its log $K_{oc}$ value of 4.22. Results of the Level III fugacity simulation for release to water show that approximately 14.2% will reside in the solid phase (suspended sediment and bed sediments) and 72.2% will reside in the aqueous phase (water column). Although the log $K_{oc}$ for the compound is in the moderate to high sorption range, the rapid hydrolysis of D4 in water at ambient temperature reduces the fraction that is expected to be adsorbed to sediments. Volatilization from water surfaces is also expected based upon the air-water partition coefficient ($K_{aw}$); the mass fraction expected to partition to air from volatilization at 25$^o$C is 13.6% (Table 4).

When D4 is released to soil through, for example, the application of sewage sludge on moist agricultural soils, approximately 88.5% of the mass fraction is estimated to partition to air. This estimate is consistent with the observation of Xu (1999) that volatilization is the major loss process of cyclic siloxanes from moist soils. Only a small percentage (11.5%) will remain in soil associated with solids, for the same reasons as described for sediment. In dry soil, D4 will be quickly degraded by clay minerals in soil to form dimethylsilanediol as the final breakdown product (Xu 1999, Xu and Chandra 1999).

# Persistence and Bioaccumulation Potential

## Environmental Persistence

### *Atmospheric Degradation*

The Level III fugacity model results (Table 4) indicate that D4, when released to air, will remain in air, where it is expected to be slowly oxidized by the gas-phase reaction with photochemically produced hydroxyl radicals. The empirically derived half-life for D4 in the gas-phase hydroxyl (OH) radical reaction is 10.6 days (Atkinson 1989, 1991; see Table 5a). This is based on an experimental reaction rate of 1.01 x $10^{-12}$ $cm^3$/mol·sec (Atkinson 1989), which may be converted to an estimated half-life of 10.6 days, assuming first-order kinetics, a 12-hour day, and 1.5 x $10^6$ OH/$cm^3$. D4 is not expected to react, or react appreciably, with other photo-oxidative species in the atmosphere, such as $O_3$, nor is it likely to degrade via direct photolysis (Atkinson 1991). Therefore, it is expected that reactions with hydroxyl radicals will be the most important fate process in the atmosphere for this substance.

Recent measurements of hydroxyl radical concentrations in an urban environment (Ren et al. 2003, Kramp and Volz-Thomas 1997, Rivett et al. 2003) suggested that there is a higher OH concentration in the urban atmosphere than that observed in the rural and marine atmosphere due to higher OH radical precursors in polluted urban areas (SEHSC 2008b). Ren et al. (2003) have measured the concentration of hydroxyl radicals in the summer atmosphere in New York City, NY, USA. The measurement was conducted over a 34-day period. The average maximum hydroxyl radical concentration was reported to be 7 x $10^6$ OH/$cm^3$ and was comparable to those measured (1–10 x $10^6$ OH/$cm^3$) in similar urban environments of the United States (Los Angeles, CA, and Nashville, TN; SEHSC 2008b) and in European countries (Kramp and Volz-Thomas 1997, Rivett et al. 2003). However, most of these measurements were carried out during the summer, when the sunlight was strong and the atmospheric photochemistry was active. The OH radical concentration measured by Ren et al. (2006) in the winter in New York City was ~5 times lower than in the summer at the same site. The measurement was conducted over a 28-day period and the maximum concentration was 1.4 x $10^6$ OH/$cm^3$. Therefore, half-lives of 5.5 to 22.8 days can be calculated assuming first-order kinetics, a 12-hour day, and a daily average hydroxyl concentration of 3.5 x $10^6$ OH/$cm^3$ and 0.7 x $10^6$ OH/$cm^3$ (daily average concentration = maximum concentration/2), in summer and winter, respectively. It is therefore concluded that D4 could be degraded more rapidly in urban centers in summer seasons when the atmospheric hydroxyl radicals are most abundant. However, when a yearly average removal half-life is considered, it is consistent with the half-life of 10.6 days estimated with a hydroxyl radical concentration of 1.5 x $10^6$ OH/$cm^3$. The degradation half-life of 10.6 days is considered critical and will be used for D4 in environmental fate modelling.

Navea et al. (2007) have investigated the effects of ozone, aerosols and solar radiation on the fate of D4 and D5 in a simulated environment chamber. They concluded that mineral aerosols such as kaolinite and hematite can significantly accelerate the removal of D4 and D5 from the gas phase of the atmosphere, especially under daytime conditions. The finding also indicated that ozone can further accelerate these removal processes for D4 and D5. Although obtained data suggested that

mineral aerosols, combined with ozone, may have significant effects on the environmental fate of cVMS in the air, it is difficult to quantitatively extrapolate the results of the simulations to realistic environmental conditions. First, it should be noted that the study was conducted under unrealistically high concentrations of cVMS, mineral aerosols and ozone. Second, mineral and carbon black samples used in the study were high-purity (>99%) analytical samples that provided maximum surface area and thus the maximally available sorption sites, i.e., ideal conditions for D4/D5 absorption. The degree to which these pure minerals are representative of the particulate matter in air is questionable. Third, it is reasonable to believe that minerals such as kaolinite and hematite can be found in atmospheric particular matter (PM); however, they are unlikely to be the most common and abundant components in atmospheric dust. In addition, it should be mentioned that the study was conducted in a simulated environment chamber and involved reacting the mineral aerosols with only one cVMS (D4 or D5) at a time. Under actual environmental conditions, thousands of chemicals compete for aerosols' adsorption sites. Therefore, in such conditions, the "effectiveness" of D4/D5 removal from ambient air could be significantly lower than that observed in the chamber's mono-component atmosphere.

Thus, it may be concluded that the degree to which aerosols and ozone accelerate degradation of cVMS in air under realistic environmental conditions is uncertain.

The AOPWIN (2000) model (Table 5b) also provides evidence indicating the potential for persistence of this substance, with a predicted atmospheric oxidation half-life of 4–19 days. Thus, the empirical and model data both demonstrate that this substance is persistent in air (half-life > 2 days) in accordance with the *Persistence and Bioaccumulation Regulations* (Canada 2000).

**Table 5a. Empirical data for persistence of D4**

| Medium | Fate process | Degradation value | Degradation endpoint/units | Reference |
|---|---|---|---|---|
| Air | OH reaction | 10.6 | Half-life (days) | Atkinson 1989, 1991 |
| Air | OH reaction | 5.5–22.8 | Half-life (days) | Ren et al. 2003, 2006 |
| Water | Biodegradation | 3.7 % | 28 d degradation | Springborn Smithers Laboratories 2005 |
| Water | Hydrolysis | 0.04–45 | Half-life (days)<br>pH 6–9<br>5–25°C | Durham 2005<br>Kozerski 2008<br>Bidleman 2008 |
| Water/sediments | Biodegradation | No biodegradation | 28d degradation | Springborn Laboratories 1991 |
| Water/sediments | Abiotic degradation | 49–588 | Half-life (days)<br>neutral pH<br>5–25°C | Xu and Miller 2008 |
| Soil (Wahiawa soils from Hawaii) | Clay-catalyzed hydrolysis | ~1 hour<br>(32% relative humidity) | Half-life (hours) | Xu 1999<br>Xu and Chandra 1999 |
| Soil (Londo soils from Michigan) | Clay-catalyzed hydrolysis | 3.54 days (32% relative humidity);<br>5.25 days (93% relative humidity) | Half-life (days) | Xu and Chandra 1999 |

**Table 5b. Modelled data for persistence of D4**

| Medium | Fate process | Degradation value | Degradation endpoint/units | Model |
|---|---|---|---|---|
| Air | Atmospheric oxidation | 8.94 | Half-life (days) | AOPWIN 2000 |
| Air | Atmospheric oxidation | 3.8–19.2 [2] | Half-life (days) | AOPWIN 2000 |
| Air | Ozone reaction | Non-reactive | Half-life | AOPWIN 2000 |
| Water | Biodegradation | 37.5 | Half-life (days) | BIOWIN 2000, Ultimate survey |
| Water | Biodegradation | 0.0 (does not biodegrade fast) | Probability | BIOWIN 2000, MITI Linear Probability |
| Water | Biodegradation | 0.0028 (does not biodegrade fast) | Probability | BIOWIN 2000, MITI Non-linear Probability |
| Water | Biodegradation | 2.9% BOD | BOD (MITI 301C)[1] | CATABOL c2004-2008 |
| Water | Biodegradation (anaerobic) | 0.2 (does not biodegrade fast) | Probability | BIOWIN 2000 |

[1] Results from CATABOL biodegradation simulation show that D4 is in the global parameter domain and metabolic domain, but out of the structural domain. The most important of these domains is the metabolic domain, and CATABOL suggests that the substance will not be degraded, as the probability of stable methyl group and aromatic ring oxidation products is low.

[2] Atmospheric oxidation half-lives re-calculated with measured OH radical concentrations from New York City in summer and winter, respectively.

### *Degradation in Water and Sediment*

The empirical hydrolysis data for D4 (Durham 2005) were critically reviewed by internal experts (Bidleman 2008); the results of these reviews are summarized below. The hydrolysis kinetics of D4 were determined by measuring the disappearance of radio-labelled $^{14}$C-octamethylcyclotetrasiloxane (D4) as a function of time based on OECD Guideline 111. Reactions were investigated in flame-sealed borosilicate glass tubes at pH values of 4, 7 and 9 and temperatures of 10˚C, 25˚C and 35˚C. The initial test concentration was targeted at 20 µg/L upon spiking, corresponding to ½–⅓ of the water solubility of D4. Tetrahydrofuran (THF) was used as a solubilizer at a concentration of 0.8% v/v. A similar hydrolysis kinetics study was also conducted for radio-labelled $^{14}$C-decamethylcyclopentasiloxane (D5) at the same laboratory (Durham 2006). The hydrolysis rates of D4 and D5 were reported to be pH-dependent and followed pseudo first-order kinetics. Both D4 and D5 were found to undergo rapid hydrolysis under acidic (pH 4) and basic (pH 9) conditions, with average half-lives ($t_{1/2}$) ranging from minutes to less than 6.5 hours for D4 and from hours to less than 6 days for D5 at 10–35˚C. Two additional hydrolysis tests were performed for D5 at near-neutral (pH 5.5 and 8) conditions at 25˚C and their $t_{1/2}$ were approximately 15 and 9 days, respectively. The half-lives at neutral pH 7 conditions increased significantly for D4 and D5. The hydrolysis products were intermediates dimethylsiloxane-alpha, and omega-diol oligomers $HO(Me2SiO)_nH$ (n=2-4 or 5), while dimethylsilanediol (DMSD) was the final hydrolysis product. Although the loss of parent compounds and poor reproducibility were reported at neutral pH, loss rates at neutral pH may be estimated using the second-order rate constants for the acid- and base-catalyzed reactions. The hydrolysis studies for D4 and D5 are thus considered reliable for this screening assessment. An

error in the calculation of the hydroxide catalytic constant, $k_{OH,}$ at temperatures other than 25˚C has, however, been identified by Bidleman (2008). Table 6 lists revised second-order rate constants for hydronium and hydroxide-catalyzed hydrolysis of D4 (Kozerski 2008).

**Table 6. Revised second-order hydrolysis rate constants (i.e., catalytic constants) for D4 (Kozerski 2008)**

| Rate constant ($M^{-1}$ $h^{-1}$) | Temperature ($^oC$) | | | |
|---|---|---|---|---|
| | 5 | 10 | 25 | 35 |
| $k_H$ | 1110 | 1560 | 3910 | 8020 |
| $k_{OH}$ | 28400 | 40200 | 73300 | 168000 |

The pseudo first-order rate constants, $k_{obs}$, for the hydrolysis of D4 can be calculated using the following kinetic equation (assuming negligible contribution of uncatalyzed hydrolysis as, confirmed by the experiments at a pH of 7):

$$k_{obs} = k_H^+[H^+] + k_{OH}\text{-}[OH^-]$$

The calculated half-lives for D4 (Table 7) under realistic Canadian environmental conditions (pH 6–9, temperature 5–25˚C) (GEMStat 2008, NOAA 2008) are in the range of 0.04–45 days.

**Table 7. Calculated D4 half-lives under realistic Canadian environmental conditions**

| Temperature ($^oC$) | Water dissociation constant $pK_w$ | pH | Rate constant k ($h^{-1}$) | Half-life (days) |
|---|---|---|---|---|
| 25 | 14 | 6 | 4.64E-03 | 6.2 |
| | | 7 | 7.72E-03 | 3.7 |
| | | 8 | 7.33E-02 | 0.4 |
| | | 9 | 7.33E-01 | 0.04 |
| 10 | 14.52 | 6 | 1.68E-03 | 17 |
| | | 7 | 1.37E-03 | 21 |
| | | 8 | 1.21E-02 | 2.4 |
| | | 9 | 0.121 | 0.24 |
| 5 | 14.73 | 6 | 1.16E-03 | 25 |
| | | 7 | 6.4E-04 | 45 |
| | | 8 | 5.30E-03 | 5.5 |
| | | 9 | 5.29E-02 | 0.55 |

New information received on microbial degradation indicates that D4 is not likely to be biodegraded in water. The 28-day ready-biodegradability test was performed in sealed vessels in accordance with OECD Draft Guideline 310 and data showed limited biodegradation (3.7%) of D4 over 28 days in a ready-biodegradation test (Springborn Smithers Laboratories 2005). These data are further supported by two of the models in Table 5b. These models indicate that the probability of biodegradation of D4 in water is effectively zero. Also, BIOWIN reported an

overall weighted conclusion of "not readily biodegradable" based on the combined results of the BIOWIN3 and BIOWIN5 models.

Experimental and modelled biodegradation data indicate that D4 has little potential to biodegrade in aqueous environments. Therefore, hydrolysis is the major degradation process for D4 in water. The weight of evidence suggests that D4 will undergo hydrolysis with half-lives of less than 45 days in Canadian water (pH 6–9, temperature 5–25˚C). It is therefore concluded that D4 does not meet the criterion of persistence in water ($t_{1/2}$ > 182 days) under the *Persistence and Bioaccumulation Regulations* (Canada 2000).

A preliminary degradation study for D4 in a water/sediment system has been received recently (Xu and Miller 2008). A modified OECD 308 guideline was followed. The study was conducted at ambient temperature (22–25ºC) with natural sediment (sandy silt, high OC content, ~70% water content and 11% organic matter, pH ~7) and water collected from deep under an uncontaminated lake. Radio-labelled D4 in diethylene glycol methyl ether was added via syringe at 10–15 spots on the surface sediment in each flask after the overlying water was carefully removed. Overlying water was again added onto the spiked sediment with minimum disturbance of sediment. Spiking of sediment instead of water ensured the substance's distribution in sediment. This properly addressed the substance's specific physical and chemical properties (high volatility and potential hydrolysis) and improved the reproducibility of the study. The concentrations of D4 measured from day 6 to day 22 (test termination) indicated that a steady state had been reached between water and sediment, with more than 95% D4 and radioactivity being detected in sediment. As demonstrated in the hydrolysis study of D4, the degradation products in sediment/water were intermediates dimethylsiloxane-alpha, and omega-diol oligomers $HO(Me2SiO)_nH$ (n=2-4), while dimethylsilanediol (DMSD) was the final degradation product. The calculated half-life for D4 degradation in sediment was 49 days at 22–25ºC. The same degradation products observed in the study and in the hydrolysis study of D4 suggested that hydrolysis was the major degradation process in the sediment/water system. The major uncertainty in the study is the lack of test replicates.

An earlier study demonstrated no biodegradation of D4 in an enclosed water/sediment system (Springborn Laboratories 1991). A modified eco-core technique was used in the study of D4 biodegradation in sediment. Natural sediment (3.2% organic carbon, pH 5.5) and water were collected from an uncontaminated pond. Radio-labelled D4 was added directly to the aqueous phase of the test systems. The rate of mineralization and disappearance of the parent compound were determined by passing $CO_2$-free air through the core chambers and trapping exhaust gases on a volatile organic trap and an alkaline $CO_2$ trap. It was concluded that no biodegradation of D4 occurred in the water/sediment test system. It was also reported that the majority of the parent compound had been volatilized and collected in the organic trap. Furthermore, by day 28 of the study, only a small amount of D4 (<5%) remained in water or had partitioned into sediment. A series of supplemental experiments were conducted to show that the small amount (<10%) of degradation products recovered from the alkaline $CO_2$ trap in the test systems and the sterile controls were caused by alkaline-catalyzed hydrolysis of D4. It is therefore concluded that D4 is not likely to biodegrade or biodegrade to a significant degree in sediment. In addition, the low D4 partitioning to sediment raises the question of whether the experimental design adequately addresses sediment degradation.

The study by Xu and Miller (2008) suggests that D4, indeed, breaks down to oligomer diols as intermediates, with the final product being dimethylsilanediol, under ambient conditions in sediment with a half-life of 49 days. Since no data were available for degradation half-lives at lower temperatures, a read-across approach using the D4 hydrolysis data was applied. The hydrolysis half-lives of D4 in water were ~6–12 times longer when water temperatures were decreased to 5–10ºC from 25ºC. Assuming a similar trend of decreases in sediment, the estimated half-lives for D4 in sediment are 294 and 588 days, at 10ºC and 5ºC, respectively. It is therefore concluded that D4 meets the criterion of persistence in sediment of $t_{1/2} > 365$ days in accordance with the *Persistence and Bioaccumulation Regulations* (Canada 2000). The extrapolation of D4 sediment degradation at lower temperatures based on hydrolysis, however, is not without uncertainty. The assumption that the loss of D4 in sediments is solely a function of hydrolysis in the pore water does not take into account the fraction that may be sorbed to the solid phase—degradation processes and rate of which are unknown.

***Degradation in Soil***

Although no empirical data on biodegradation in soils are available, as noted above, microbial degradation of D4 in water and a water/sediment system is negligible based on the ready-biodegradation test (Springborn Smithers Laboratories 2005), sediment biodegradation test (Kent et al.1994) and predictions of five of the six biodegradation models (Table 5b).

Xu (Xu 1999, Xu and Chandra 1999) has extensively investigated potential degradation pathways of cyclosiloxanes, including D4, D5 and D6, in Wahiawa soil from Hawaii at room temperature and 32% relative humidity. He concluded that the ring-opening polymerization reaction to form polydimethylsiloxane (PDMS), the demethylation of cyclosiloxanes and the hydrolysis were insignificant in soils at concentrations of < 200 mg/kg dry weight. Clay-catalyzed hydrolysis of D4 was observed in highly weathered Wahiawa soils. Tetramer, trimer, dimer and monomer diols were reported as the intermediates, and dimethylsilanediol (DMSD) was reported as the final hydrolysis product. Upon re-wetting of the soil after seven days, only D4, D3 and DMSD were present, and a small amount of D5 and D6, indicating that higher oligomer diols may undergo backward reaction of ring-opening process. The hydrolysis degradation half-life of D4 on Wahiawa soil (55% clay content, 2.1% water content) was ~1 hour at 22ºC under dry soil conditions. It was suggested that the dryness of soil severely limits the biological activity but promotes abiotic reactions such as surface-acid-catalyzed hydrolysis of PDMS, a polymer with the same dimethylsiloxane backbone as cyclosiloxanes (Xu 1999). The degradation rates of cyclosiloxanes were highly dependent on soil moisture, clay type and clay content, as well as the size of the siloxane molecules that determine the rate of diffusion to the surface catalytic sites. The hydrolysis rate of D4 decreased in temperate Londo soils from Michigan (22% clay content) to 3.54 days half-life at 32% relative humidity and 5.25 days half-life at 93% relative humidity. However, most of the D4 remained in Londo soil during the 21-day incubation in an enclosed system at 100% relative humidity, while the degradation half-life of D4 was less than 1 day in highly weathered Wahiawa soil under the same humidity. Volatilization becomes the major loss mechanism for D4 under such soil conditions in an open system.

While investigating the influence of clay types on the degradation potential of polydimethylsiloxanes (PDMS), Xu et al. (1998) demonstrated that PDMS was degraded by different clay minerals even though their catalytic activities varied. The widespread presence of these clay minerals suggests that D4 will undergo clay-catalyzed degradation in soil as long as critical soil conditions such as low moisture content are present, despite the tremendous diversity of Canadian soils.

Based on the available empirical studies that show the potential for rapid clay-catalyzed hydrolysis in surface soils, D4 is not considered persistent in soil according to the criterion of $t_{1/2}$ >182 days as stated in the *Persistence and Bioaccumulation Regulations* (Canada 2000).

The available empirical and modelled data indicate that D4 meets the persistence criteria for air (half-life ≥ 2 days) and sediments (half-life ≥ 365 days) as set out in the *Persistence and Bioaccumulation Regulations* (Canada 2000), but that it does not meet the half-life criterion for soil and water (i.e., half-lives are ≤ 182 days).

***Long-range Transport Potential***

The Transport and Persistence Level III Model (TaPL3 2000), a regional model, was used to estimate the characteristic travel distance (CTD) of D4. CTD is defined as the maximum distance travelled in air by 63% of the substance. Beyer et al. (2000) have proposed that CTDs of >2000 km represent high long-range atmospheric transport potential (LRATP), those of 700–2000 km represent moderate LRATP, and those of <700 km represent low LRATP. Based on the CTD estimate of 5284 km, the long-range atmospheric transport potential of D4 is judged to be high. This means that D4 is subject to atmospheric transport to remote regions such as the Arctic.

**Table 7. Model-predicted characteristic travel distance for D4**

| Characteristic travel distance | Model (reference) |
|---|---|
| 5284 km | TaPL3 v. 2.10 (TaPL3 2000) |
| 5254 km | OECD LRTP POPs Tool v.2.0 (Scheringer et al. 2006) |

The OECD POPs Screening Model can be used to help identify chemicals with high persistence and long-range transport potential (Scheringer et al. 2006). The OECD model is a global model which compartmentalizes the earth into air, water and soil. This model is "transport-oriented" rather than "target-oriented," as it simply identifies the CTD without indicating specifically where a substance may be transported (Fenner et al. 2005). Klasmeier et al. (2006) have suggested that a threshold of 5098 km, based on the model's CTD estimate for 2,2′,3′,4,4′,5,5′-Heptachlorobiphenyl (PCB-180), can be used to identify substances with high long-range transport potential. PCB-180 has been found in remote regions. The CTD calculated for D4 using the OECD model is 5254 km, indicating that D4 has a high potential for long-range transport in air.

The OECD POPs Screening Model also calculates the transfer efficiency (TE), which is the percentage of emission flux to air that is deposited to the surface (water and soil) in a remote region (TE = D/E x 100, where E is the emission flux to air and D is the deposition flux to surface media in a target region). The TE for D4 was calculated to be 4.4E-06%, which is well

below the boundary of 4.65E-04% (2,4,4'-trichlorobiphenyl, or PCB-28) established for the model's reference substances that are empirically known to be deposited from air to soil or water. The low TE means that D4 has the potential for long-range travel in the atmosphere without being deposited to Earth's surface in any particular remote region. In addition, the log $K_{oa}$ and log $K_{aw}$ of D4 suggest that it will also have a low Arctic contamination potential (ACP) when examined using chemical partitioning space plots as described by Wania (2003, 2006).

A preliminary monitoring study of a remote ecosystem was conducted in Lake Opeongo, the largest lake in Algonquin Provincial Park, Ontario, Canada. The lake is relatively remote from potential sources of cVMS from sewage and runoff. Therefore, it was assumed that the only significant source of cVMS to the lake would be from atmosphere deposition (Powell 2008). Preliminary analysis of sediments and zooplankton samples for cVMS found no D4, suggesting that atmospheric deposition is not a significant source of D4 to Lake Opeongo. Limits of detection were 23.9 ng (background corrected mass) for both sediments and zooplankton.

It is therefore concluded that D4 has the potential to be transported over long distances in the atmosphere. However, the modelled TE for D4 is low, which suggests that it lacks the potential to be deposited in water or soil in remote regions. The monitoring results of Lake Opeongo also supported the low atmospheric deposition potential for D4. It is expected that airborne D4 will be eventually degraded by hydroxyl radicals in air.

**Potential for Bioaccumulation**

The empirical and modelled log $K_{ow}$ values for D4 (Table 2) suggest that this substance has the potential to bioaccumulate in biota.

***In the Aquatic Compartment***

Empirical data indicate that D4 has the ability to bioconcentrate in aquatic organisms. A bioconcentration study for D4 was conducted on fathead minnows (*Pimephales promelas*) in a flow-through system (Fackler et al. 1995). The uptake of radio-labelled [$^{14}$C] D4 in fish tissue was investigated at a concentration of 0.00023 mg/L (measured) over a 28-day period and depuration over a 14-day period. The mean steady-state bioconcentration factor ($BCF_{ss}$) was calculated to be 12 400 L/kg based on concentrations measured from day 7 to day 28. The kinetic bioconcentration factor ($BCF_k$) was calculated to be 13 400 L/kg based on the uptake and depuration rates ($k_1/k_2$ = 2450/0.183). Fish tissue analysis also indicated that the depuration half-life for radio-labelled D4 was 7–12 days and that an average of 45% of accumulated D4 still remained in fish after 14 days of depuration. The metabolic potential of D4 was also investigated during this BCF study. In each tissue type, the entire extracted radioactivity (> 95%) was identified as D4, indicating that metabolism of D4 is negligible.

**Table 9a. Empirical bioaccumulation data for D4**

| Test organism | Endpoint[1] | Value | Reference |
|---|---|---|---|
| *Pimephales promelas* (fathead minnow) | $BCF_{ss}$ | 12 400 L/kg wet wt | Fackler et al. 1995 |
| *Pimephales promelas* (fathead minnow) | $BCF_k$ | 13 400 L/kg wet wt | Fackler et al. 1995 |
| *Oncorhynchus mykiss* (rainbow trout) | BMF | 0.62–0.75 (lipid normalized) | Drottar 2007; Domoradzki 2008a, 2008b; SEHSC 2008b |

[1] $BCF_{ss}$: steady-state bioconcentration factor; $BCF_k$: kinetic bioconcentration factor; BMF: biomagnification factor

New experimental data have also been received on a bioaccumulation study of aquatic organisms. A dietary bioaccumulation study of $^{14}$C-octamethylcyclotetrasiloxane (radiochemical purity 99.1%) in rainbow trout (*Oncorhynchus mykiss*) was carried out in a flow-through system (Drottar 2007; see Table 9a of this assessment) for 35 days, followed by 42 days of depuration. Fish were fed trout chow dosed with an average measured parent concentration of 457 µg/g. Feeding was adjusted to provide a feeding rate of 3% wet body weight per day. The higher feeding rate was modified to provide better instrument detection and is considered justified. No adverse effects on the fish were observed throughout the study. The entire extracted radioactivity from fish was identified as parent D4 and the non-extractable radioactivity from fish tissue was ~7%, indicating that metabolism of D4 is very limited. The calculated elimination constant indicated that a period of 57 days would be required to achieve 90% of steady state instead of the 35-day uptake in the test. Therefore, a fish residue at day 57 uptake was extrapolated and the corrected fish biomagnifications factor, BMF (lipid-normalized), was 0.62. The kinetic BMF was calculated by a one-compartment model accounting for fish growth rates during the uptake and the depuration phases of the study, the amount of D4 in the fish over time, the mass of the fish over time, as well as the food consumption rate. The metabolic rate constant, $k_M$, was assumed to be zero. Fish growth rates were calculated using linear regression (Domoradzki 2008a, 2008b). The resultant kinetic BMF (lipid-normalized) was 0.75. The BMF values agreed reasonably well. It is therefore considered that D4 did not show biomagnification potential in the laboratory fish dietary study.

The Arnot-Gobas model (Arnot and Gobas 2003) can be used to predict the bioaccumulation factor (BAF) of this substance, while taking into account any potential metabolism using a metabolic rate constant ($k_M$). The available BCF and BMF *in vivo* tests data were used to derive an *in vivo*-based metabolic rate constant according to the method of Arnot et al. (2008a). In this method, $k_M$ is derived according to the following equation:

$$k_M = (k_1\varphi/BCF) - (k_2 + k_E + k_G) \quad (1)$$

where

$k_M$ = the metabolic rate constant (1/days)
$k_1$ = the uptake rate constant (Arnot and Gobas 2003)
$\varphi$ = fraction of freely dissolved chemical in water (Arnot and Gobas 2003)
BCF = the available empirical bioconcentration factor
$k_2$ = the elimination rate constant (Arnot and Gobas 2003)
$k_E$ = fecal egestion rate constant (Arnot and Gobas 2003)
$k_G$ = growth rate constant (Arnot and Gobas 2003)

The method of Arnot et al. (2008a) provides for the estimation of confidence factors (CF) for the $k_M$ to account for error associated with the *in vivo* data (i.e., measurement variability, parameter estimation uncertainty and model error). A CF of ± 2.1 was calculated for the available BCF data.

Because metabolic potential can be related to body weight and temperature (e.g., Hu and Layton 2001, Nichols et al. 2007), the $k_M$ was further normalized to 15°C and then corrected for the body weight of the middle trophic level fish in the Arnot-Gobas model (184 g) (Arnot et al. 2008b). The middle trophic level fish was used to represent overall model output as suggested by the model developer (Arnot, personal communication to Bonnell M. of Environment Canada, 2008, [unreferenced]) and is most representative of fish weight likely to be consumed by an avian or terrestrial piscivore. After normalization routines, the $k_M$ ranges from ~0.008 to 0.08 with a median value of 0.02.

**Table 9b. Metabolism corrected BCF and BAF estimates using Arnot-Gobas (2003)**

| $k_M$ (middle trophic level normalized) $day^{-1}$ | log $K_{ow}$ used | Arnot-Gobas BCF | Arnot-Gobas BAF |
|---|---|---|---|
| 7.80E-03 (2.5%) | 6.5 | 12 589 | 467 735 |
| 2.25E-02 (average) | 6.5 | 4365 | 89 125 |
| 8.18E-02 (97.5%) | 6.5 | 1 413 | 12 022 |

The calculated $k_M$ values based on *in vivo* experiments suggest that the rate of metabolism of D4 is quite low (≤ 0.08 $d^{-1}$ at best). The experimental BCF study on fathead minnows (Fackler et al. 1995) and the dietary bioaccumulation study on rainbow trout (Drottar 2007) demonstrated almost full recovery of the parent compound (>95%), which generally supports the idea of limited metabolism of D4. The calculated BCF of 12 589 using the lower percentile rate constant (~0.008) compares closely with the experimental BCF values from Fackler et al. (1995). Therefore, the corresponding BAF, corrected using this metabolic rate constant (467 735), was used to represent the bioaccumulation potential of D4 for fish in Canadian waters.

***In the Sediment Compartment***

The biota-sediment accumulation factor (BSAF) for D4 can be calculated using data from a *Chironomus tentans* (midge) sub-chronic toxicity study (Kent et al. 1994). Midge were exposed to D4 in sediment of low (LOC), medium (MOC), and high (HOC) organic carbon content ranging from 0.27% to 4.1%. The average BSAFs were calculated (BSAF = $C_{organism\ tissue}$ mg/kg /$C_{sediment}$ mg/kg) to be 0.7, 1.3 and 2.2, respectively, for the HOC, MOC and LOC phases. The results indicate that D4 may have some potential to bioaccumulate through exposure to sediment. However, this study did not specify whether the gut contents of test organisms had been purged before calculation of BSAF values. The BSAF value may thus be over-estimated due to the presence of D4 on sediments within the gut of the invertebrates.

***In the Soil Compartment***

No bioaccumulation information for D4 was available for the soil compartment.

### *In the Terrestrial Compartment*

The Gobas mass-balance bioaccumulation model for terrestrial organisms (Gobas et al. 2003) uses a chemical's octanol-air and octanol-water partition co-efficient ($K_{oa}$ and $K_{ow}$) to estimate the chemical's biomagnification (BMF) potential in terrestrial food chains. It was estimated that chemicals with a log $K_{oa} > 5$ can biomagnify in terrestrial food chains if log $K_{ow}$ is > 2 and the rate of chemical transformation or metabolism is low. A log $K_{oa}$ of 4.34 indicates that D4 does not have the potential to biomagnify in terrestrial food chains.

### *Summary of the Bioaccumulation Potential of D4*

Overall, the empirical steady-state and kinetic fish BCF study, optimized for water-borne exposure, has shown that the bioconcentration potential for D4 from water is high (i.e., ≥5000). Although the log $K_{ow}$ for D4 would suggest that dietary uptake of D4 will be significant and may predominate, it is not outside the range of log $K_{ow}$ values where bioconcentration in laboratory studies has been observed to be significant for many chemicals (e.g., Arnot and Gobas 2006). Predicted BCF values, corrected for metabolism, are also >5000 and generally agree with empirical BCF values. Empirical and predicted BCF values exceed 5000, which suggests that there may be potential for high bioconcentration in other organisms at different trophic levels as well as fish, especially those with lower growth or metabolic rates (e.g., autotrophs).

Predicted BAF values are also high and exceed 5000. As with other models, some uncertainty exists with predicted BCF and BAF values (e.g., uncertainty increases at higher log $K_{ow}$ values, as few chemicals have been studied for bioaccumulation in this range). Higher confidence is attributed to the predicted BAF value with a corresponding predicted BCF that most closely compares with the empirical BCF data (i.e., BAF = ~4.7E05). The mass-balance kinetic model used is based on "first principles," meaning that the most important domain of the model is that a chemical obeys the principal mechanism of the model, in this case passive diffusion. D4 meets this domain and is within the model's log $K_{ow}$ and molecular weight boundaries as well. Therefore, the predictions for bioaccumulation are also considered to be applicable to D4.

BSAF values for D4 would suggest a relatively low level of accumulation in sediment macroinvertebrates. As this is the only sediment bioaccumulation test available for cVMS and there are no predictive models for sediment organisms, testing or field evidence at more realistic environmental loadings would help verify these values. The BMF values generated for D4 are less than 1, which suggests that there may be low biomagnification potential in fish for D4, but there is currently no evidence to suggest that this may be the case for other trophic levels. Field mesocosm studies are currently under way to examine trophic transfer of cVMSs in aquatic food webs, but these data are not yet available for full evaluation and were not considered for this assessment.

Finally, there is conflicting evidence on the bioaccumulation potential of D4 tested under laboratory conditions. BMF studies in fish and BSAF studies in invertebrates suggest that the bioaccumulation potential of D4 is low, possibly due to reduced bioavailability. Available optimized BCF test data as well as predictive modelling suggest that there may be potential for significant bioconcentration of D4 in fish and potentially at lower levels of an aquatic food web.

Therefore, it is reasonable to conclude that D4 has bioaccumulation potential in biota. However, considering the conflicting evidence, it is not possible to conclude that D4 meets the criterion for bioaccumulation (BCF or BAF ≥ 5000) as set out in the *Persistence and Bioaccumulation Regulations* (Canada 2000).

## Potential to Cause Ecological Harm

### Ecological Effects Assessment

### A - In the Aquatic Compartment

There is experimental evidence that D4 causes harm to aquatic organisms at very low concentrations (e.g., $LC_{50}$ < 1 mg/L) (Table 10a). The empirical ecotoxicity values indicate that D4 is very toxic to sensitive aquatic organisms, with extremely high short- and long-term toxicity below its solubility limit (0.056 mg/L, Table 2). For small-sized (≤ 1g) rainbow trout, the lowest concentration causing 50% mortality ($LC_{50}$) in an acute test is 0.01 mg/L, with a no-observed-effect concentration (NOEC) of 0.0044 mg/L and a lowest-observed-effect concentration (LOEC) of 0.0069 mg/L. Affected fish exhibited darkened pigmentation, loss of equilibrium, and lethargic behaviour before they died, consistent with a narcosis mechanism of toxicity (Sousa et al. 1995). A fish early life-stage study was also reported by Sousa et al. (1995). Rainbow trout embryos were exposed to D4 at concentration levels of 0.00025–0.0044 mg/L for 93 days. No adverse effects were observed to embryo viability, hatching success, larval survival, and growth at all treatment levels. Therefore, the chronic NOEC for 93-day fish early life-stage is 0.0044 mg/L, the highest concentration tested.

D4 caused significant mortality at 0.015 mg/L during a 21-day chronic toxicity study for the water flea, *Daphnia magna*, an important species of zooplankton in ecosystems. The chronic NOEC for *Daphnia magna* is 0.008 mg/L for survival and reproduction, and the LOEC for survival is 0.015 mg/L (Sousa et al. 1995).

**Table 10a. Empirical aquatic toxicity data for D4**

| Test organism | Type of test | Duration | Endpoint[1] | Value (mg/L) | Reference |
|---|---|---|---|---|---|
| Rainbow trout *Oncorhynchus mykiss* | Acute | 14 d | $LC_{50}$ | 0.010 | Sousa et al. 1995 |
| Rainbow trout *Oncorhynchus mykiss* | Acute | 14 d | NOEC | 0.0044 | Sousa et al. 1995 |
| Rainbow trout embryos *Oncorhynchus mykiss* | Chronic | 93 d | NOEC | 0.0044 | Sousa et al. 1995 |
| Shrimp | Acute | 96 hr | $LC_{50}$ | > 0.0091 | Sousa et al. 1995 |
| Sheepshead minnow *Cyprinodon variegatus* | Acute | 14 d | NOEC | 0.063 | Sousa et al. 1995 |
| Sheepshead minnow *Cyprinodon variegatus* | Acute | 14 d | $LC_{50}$ | > 0.063 | Sousa et al. 1995 |
| Water flea *Daphnia magna* | Acute | 48 hr | NOEC | 0.015 | Sousa et al. 1995 |
| Water flea *Daphnia magna* | Chronic | 21 d | NOEC | 0.008 | Sousa et al. 1995 |
| Water flea *Daphnia magna* | Chronic | 21 d | LOEC | 0.015 | Sousa et al. 1995 |
| Midge | Chronic | 14 d | NOEC | ≥ 0.015 | Kent et al. 1994 |
| Freshwater algae *Selenastrum capricornutum* | Acute | 96 hr | $EC_{50}$ | invalid | Springborn Laboratories 1990 |

[1] $LC_{50}$: the lowest concentration causing 50% mortality; $EC_{50}$: the lowest concentration causing sublethal effects in 50% of the population; NOEC: no-observed-effect concentration; LOEC: lowest-observed-effect concentration

New experimental data were received, specifically an acute toxicity study on freshwater algae, *Selenastrum capricornutum*, in a closed system under a 96-hour static exposure condition (Springborn Laboratories 1990). The toxicity test was performed following the *Toxic Substances Control Act* (TSCA) standard test method for algae. Algae were exposed to a saturated solution of D4 (>99% active ingredient). However, the concentrations of the test solution decreased steadily from 0.022 mg/L at test initiation to under detection limit (< 0.001 mg/L) at the end of the 96-hour test. The pH was 7.5 at test initiation and increased to 10.0 during the 96-hour test, which reflected photosynthesis and respiration of the algae. The temperature during the study ranged from 23˚C to 24˚C. A decrease in mean cell densities was observed in D4-exposed algae. However, a significant reduction in cell density was observed in the closed-system control compared to that of the open system due to limited oxygen and carbon dioxide. Considering the rapid decrease of D4 concentrations during the test and the uncertainty surrounding the reduced growth rate in the control, the study is considered invalid.

The acute and chronic toxicity of D4 was predicted using ECOSAR (2004). Predicted results are given in Table 10b.

**Table 10b. Modelled aquatic toxicity values for D4**

| Organism | Type of test | Endpoint[1] | Duration | Concentration (mg/L) | Model |
|---|---|---|---|---|---|
| Fish | Acute | $LC_{50}$ | 14 d | 0.049 | ECOSAR 2004 |
| Fish | Chronic | ChV | 30 d | 0.003 | ECOSAR 2004 |
| *Daphnia* | Chronic | $EC_{50}$ | 16 d | 0.007 | ECOSAR 2004 |
| Green Algae | Acute | $EC_{50}$ | 96 h | 0.015 | ECOSAR 2004 |

[1] LC50: the lowest concentration causing 50% mortality; EC50: the lowest concentration causing 50% effects; ChV is the geometric mean of the NOEC (no-observed-effect concentration) and LOEC (lowest-observed-effect concentration).

The modelled 30-day fish result (ChV = 0.004 mg/L) for D4 using ECOSAR is in reasonably good agreement with the empirical fish data (14d ChV = 0.0055 mg/L, the geometric mean of the fish 14-day NOEC and LOEC); the predicted $LC_{50}$ for fish 14-day exposure is ~ 5 times lower than the empirical fish 14-day $LC_{50}$ (0.010 mg/L). The predicted $EC_{50}$ for 16-day exposure to *Daphnia* is in agreement with the empirical NOEC in a 21-day exposure to *Daphnia*, indicating that the model overestimated the effect concentration for *Daphnia*. The modelled result suggests that there is also a possibility of adverse effects (i.e., acute EC50 < 1 mg/L) in algae at D4 concentration of 0.016 mg/L, however, some uncertainty exists with the predicted algae value since the log $K_{ow}$ for D4 (6.49) is slightly higher than the log $K_{ow}$ cut off (6.4) for reliable prediction of algae toxicity. Lack of siloxanes in the model's training set also adds uncertainty into the predicted values. Therefore, the predicted aquatic toxicity values were not considered further in this screening assessment.

The experimental data indicate that D4 has the potential to be highly hazardous to aquatic organisms (i.e., acute LC/$EC_{50}$<1.0 mg/L and chronic NOEC < 0.1 mg/L). However, it is interesting to note that the toxicity to both trout and *Daphnia* were not observed until these organisms were exposed to D4 for 7–14 days. The observation is consistent with the fish bioconcentration study which noted that the concentrations in fish tissue reached steady state after 7–14 days of exposure to D4, indicating that the observed toxicity may relate to D4 uptake kinetics and sufficient accumulation of the substance is required to cause toxicity (Sousa et al. 1995). It should also be mentioned that mortality was not observed in other aquatic organisms, such as shrimp or sheephead minnow and/or larger trout, as shown in the fish dietary and metabolism studies, indicating that D4 could be more toxic to sensitive aquatic organisms and/or aquatic organisms of sensitive early-life stages.

## B – In Other Environmental Compartments

### *In the Sediment Compartment*

The sub-chronic toxicity of D4 in sediments was evaluated using *Chironomus tentans* (midges) in a series of 14-day exposures in three different sediments and in water only (Kent et al. 1994). Tests were conducted with sediments of low (LOC), medium (MOC), and high (HOC) organic carbon contents ranging from 0.27% to 4.1%. Mortality was observed at 250 and 170 mg/kg dw for the MOC and HOC sediments, respectively, and growth effects were observed at

130 mg/kg dwfor the LOC sediments. The NOECs for mortality were 130, 120, and 54 mg/kg for the HOC, MOC, and LOC sediments, respectively.

A prolonged sediment toxicity study to midges, *Chironomus riparius*, was conducted using spiked sediment (Krueger et al. 2008). The midges were exposed to mean measured concentrations of D4 ranging from 6.5 mg/kg dw to 355 mg/kg dw for 28 days at 20˚C. The organic carbon content of the formulated sediment was 4.1%. The overlaying water was renewed every week due to the high ammonia measured in the test chamber. The observed NOEC for both percent survival and emergence was determined to be 44 mg/kg (measured). The calculated $LC_{50}$ value for survival was 114 mg/kg and the observed LOEC for the emergence ratio was 131 mg/kg. Midges exposed to 355mg/kg of D4 showed a statistically significant reduction in development and the NOEC and LOEC for midge development was determined to be 131 mg/kg and 355mg/kg, respectively.

It should be mentioned that the sediment toxicity test was performed with sediment of high organic carbon content. The sediment toxicity data from Kent (1994) demonstrated an increased D4 toxicity, with decreased organic matter content of sediment due to increased bioavailability. Therefore, it is concluded that D4 is more likely to cause adverse effects to sediment-dwelling organisms in sediments with low organic matter content (i.e., mineral-rich sediments).

### *In the Soil Compartment*

No effects studies for soil organisms were found for D4 or its analogues.

### *In the Terrestrial Compartment*

No ecological studies were identified for terrestrial wildlife. Laboratory studies on mammals are discussed under the “Potential to Cause Harm to Human Health” section in this screening assessment.

## Ecological Exposure Assessment

### *In Air*

In Canada, preliminary environmental measurements of volatile methyl-siloxanes, including D4, were conducted in the Great Lakes region during February and March of 2006 (personal communication, Environment Canada, Canadian Centre for Inland Waters, 2007 [unreferenced]). Eighteen outdoor air samples were collected from rural and urban areas in Ontario and D4 was present in almost all the samples collected, at concentration levels of $< 1$ µg/m$^3$. This result is in agreement with what has been reported in other jurisdictions (Table 11a).

It is, however, possible that the detection of D4 in ambient air is in part a result of sample contamination. Volatile cyclosiloxanes are present in a wide variety of commercial products, and both Canadian and Nordic monitoring programs have reported problems of high levels of cyclosiloxanes in sample blanks. Very few duplicate measurements are available for outdoor air

monitoring and the few that are available exhibit poor reproducibility (personal communication, Environment Canada, Canadian Centre for Inland Waters, 2007 [unreferenced]).

**Table 11a. Concentrations of D4 in air**

| Medium | Location; year | Concentration | Reference |
|---|---|---|---|
| Air | Great Lakes region, Canada; February and March 2006 | < 1 µg/m$^3$ | see footnote 2 |
| Air | Nordic countries[1]; 2004–2005 | 0.08–4 µg/m$^3$ | Norden 2005 |

[1] Outdoor samples (n=24) were collected in Nordic countries. The detection limit for D4 was 0.006 µg/m$^3$.
[2] personal communication, Environment Canada, Canadian Centre for Inland Waters, 2007 [unreferenced]

### *In Water*

In Canada, water from a total of nine sewage treatment plants (STPs), including conventional secondary and tertiary water treatment plants and lagoons, in large urban centres in southwestern Ontario was sampled during October 2005 and winter 2005 (personal communication, Environment Canada, Canadian Centre for Inland Waters, 2007 [unreferenced]). D4 was detected in both influents and effluents with concentration levels of D4 at < 2–24 µg/L and < 2–2.92 µg/L, respectively, in the influents and effluents being measured. Seasonal differences of D4 in influents to STPs were also noted; most influent concentrations increased from < 2 µg/L in the fall to 2.78–21.42 µg/L in winter. Seasonal differences in D4 concentrations in effluents from STPs were insignificant. Similar monitoring results have been reported in other jurisdictions (Table 11b).

**Table 11b. Concentrations of D4 in water**

| Medium | Location; year | Concentration | Reference |
|---|---|---|---|
| STP influents | Southwestern Ontario, Canada; October 2005 | < 2–24 µg/L | see footnote 4 |
| STP effluents | Southwestern Ontario, Canada; October 2005 | < 2–2.92 µg/L | see footnote 4 |
| STP influents | United States | 0.64–7.09 µg/L | HydroQual Inc. 1993 |
| STP effluents | United States | 0.06–0.41 µg/L | HydroQual Inc. 1993 |
| Water | Lake Pontchartrain, Louisiana, U.S. | ~0.03 µg/L | McFall et al. 1985 |
| Drinking water | United States | Qualitatively detected | Wallace et al. 1984 |
| Water | Background and urban sites[1], Nordic countries | < 0.1 (d.l.) | Norden 2005, NILU 2007 |
| STP influents | Nordic countries[2] | < 0.3–3.7 µg/L | Norden 2005, NILU 2007 |
| STP effluents | Nordic countries[3] | < 0.08 (d.l.) – 0.11µg/L | Norden 2005, NILU 2007 |

[1] A total of 28 sampling sites excluding STP influents and effluents
[2] 7 STP influent sampling sites
[3] 12 STP effluent sampling sites
[4] personal communication, Environment Canada, Canadian Centre for Inland Waters, 2007 [unreferenced]
d.l. = detection limit

### *In Sediments*

In Canada, surface sediments and sediment cores were collected from Lake Ontario in July 2006 and analyzed for D4, D5, and D6 (Powell and Kozerski 2007). Surface sediments consisting of the upper 5 cm of sediment were collected from Toronto Harbour and the Kingston Basin. Sediment cores, which were sectioned into strata 5 mm thick, were collected from the Rochester, Mississauga, and Niagara basins. The surface sediments from Toronto Harbour and Kingston Basin contain moderate total organic carbon (TOC = 2.1–2.4% dw), while sediment cores contain high TOC (4–5% dw). Loss-on-ignition analysis of sediments also demonstrated lower water contents in surface sediments (55–70% ww) than in sediment cores (80–89%). Sediments in Toronto Harbour and the four sedimentary basins are known to be contaminated with a variety of organic compounds that enter the lake through direct discharges of treated wastewater, flow from the upper Great Lakes (Erie, Huron and Michigan) and the Niagara River, and atmospheric deposition. Surface sediments from Toronto Harbour contained the highest concentration of D4, at 0.29 µg/g dry weight. In contrast, concentrations of the cyclic siloxane materials in the surface sediments and sediment cores from the four sedimentary basins were all less than the analytical method detection limit, which was 0.006 µg/g for D4. Similar monitoring results have been reported in other jurisdictions, where D4 was detected in surface sediments from urban areas and point sources (Table 11c).

A preliminary monitoring study of a remote ecosystem was conducted in Lake Opeongo, the largest lake in Algonquin Provincial Park, Ontario, Canada. The lake is relatively remote from potential sources of cVMS from sewage and runoff (Powell 2008). Preliminary analysis of surface sediment and sediment core samples found no D4, with a limit of detection of 23.9 ng (background corrected mass).

The sediment monitoring results from Lake Opeongo and the Lake Ontario area suggest that D4 contamination is more likely to be found near urban centres and point sources.

**Table 11c. Concentrations of D4 in sediments**

| Medium | Location; year | Concentration | Reference |
|---|---|---|---|
| Surface sediments | Toronto Harbour, Canada; July 2006 | 0.29 µg/g dw | Powell and Kozerski 2007 |
| Surface sediments | Kingston Basin, Canada; July 2006 | < 0.006 µg/g dw (d.l.) | Powell and Kozerski 2007 |
| Sediment cores | Rochester, Mississauga, and Niagara basins, Canada; July 2006 | < 0.006 µg/g dw (d.l.) | Powell and Kozerski 2007 |
| Surface sediments | Lake Opeongo, Algonquin Provincial Park, Ontario, Canada; October 2007 | < 23.9 ng (d.l.)[2] | Powell 2008 |
| Sediment cores | Lake Opeongo, Algonquin Provincial Park, Ontario, Canada; October 2007 | < 23.9 ng (d.l.)[2] | Powell 2008 |
| Sediments | Nordic countries[1] | < d.l. (varied from sample to sample) – 0.084 µg/g dw | Norden 2005, NILU 2007 |

[1] A total of 30 sediment sampling sites; [2] Background corrected mass as reported in the preliminary study; dw = dry weight; d.l. = detection limit

### *In Soil*

D4 may enter soil from land application of sewage sludge. No monitoring data for D4 in sewage sludge are available for Canada. In Europe, D4 is present in sewage sludge at levels ranging from the µg/kg level up to 2.7 mg/kg dry weight (Norden 2005, Kaj et al. 2005, NILU 2007).

No monitoring data are available for D4 in Canadian soil. D4 concentrations in two soil samples from the Faroe Islands were below detection limit (< 10 ng/g dw) (Norden 2005).

### *In Biota*

A preliminary monitoring study of a remote ecosystem was conducted in Lake Opeongo, the largest lake in Algonquin Provincial Park, Ontario, Canada. The lake is relatively remote from potential sources of cVMS from sewage and runoff (Powell 2008). Preliminary analysis of zooplankton samples found no D4. Bulk zooplankton samples were pooled into a single sample for each of the two locations from the lake without being sorted into species. The limit of detection was 23.9 ng (background corrected mass).

In Europe, D4 was detected in the livers of fish and marine mammals in Nordic countries. The concentrations varied with species, gender and age. Among marine mammals monitored in Nordic countries, D4 was only detected in seal blubber in Denmark, at the level of 12 ng/g wet weight (ww) (Norden 2005). The concentrations in both freshwater and marine fish, from sampling sites in urban areas and near STPs, were generally in the range of < 5–13 ng/g ww, except for one sample of cod liver (9 livers pooled) collected at a location near a city centre in Norway that had a higher concentration of D4 (70 ng/g ww). The follow-up environmental monitoring program conducted by the Norwegian government confirmed that the same level of D4 was present in cod livers (NILU 2007). D4 was also found in common mussels, flounder livers and fillets, and in cod stomach contents from Norway in the same monitoring program. D4 was also detected in fish samples in Germany at concentrations ranging from 100 to 1 000 ng/g ww (SEHSC 2005). D4 was not detected in fish muscle samples in Sweden (Kaj et al. 2005).

The presence of D4 in European biota indicates that despite the low detected concentrations or even non-detection of the substance in or near fish habitats, D4 is available in the environment for biota to take up and accumulate.

**Table 11d. Concentrations of D4 in biota**

| Organism | Location; year | Concentration | Reference |
|---|---|---|---|
| Zooplankton | Lake Opeongo, Algonquin Provincial Park, Ontario, Canada; October 2007 | < 23.9 ng/g (d.l.) | Powell 2008 |
| Marine fish livers | Nordic countries[1]; 2002–2004 | < 5 (d.l.)–70 ng/g ww | Norden 2005 |
| Freshwater fish livers | Nordic countries[2]; 2002 | < 5 (d.l.)–8.9 ng/g ww | Norden 2005 |
| Marine mammals | Nordic countries[3]; 2002 | < 5 (d.l.)–12 ng/g ww | Norden 2005 |
| Seabird eggs | Nordic countries[4]; 2000–2005 | < 5 ng/g ww (d.l.) | Norden 2005 |
| Common mussels | Norway[5]; 2006 | 1.3–2.3 ng/g ww | NILU 2007 |
| Flounder livers | Norway[6]; 2006 | 2.6 ng/g ww | NILU 2007 |
| Flounder fillets | Norway[6]; 2006 | 1.9 ng/g ww | NILU 2007 |
| Cod stomach contents | Norway[7]; 2006 | 5.0–9.3 ng/g ww | NILU 2007 |
| Cod livers | Norway[7]; 2006 | 81.2–134.4 ng/g ww | NILU 2007 |
| Fish | Rhine River[8], Germany | 100 (q.l.)–1000 ng/g ww | SEHSC 2005 |

[1] A total of 11 sampling matrices for marine fish
[2] A total of 10 sampling matrices for freshwater fish
[3] A total of 7 sampling matrices for marine mammals
[4] A total of 17 sampling matrices for seabird eggs
[5] A total of 3 sampling matrices for mussel
[6] A total of 2 sampling matrices for flounder
[7] A total of 3 sampling matrices for cod
[8] A total of 5 fish matrices were sampled from Rhine River; a Danish salmon obtained from an unspecified location showed no detectable D4
ww = wet weight; d.l. = detection limit; q.l. = quantification limit

## Characterization of Ecological Risk

The approach taken in this ecological screening assessment was to examine various supporting information and develop conclusions based on a weight-of-evidence approach and using the precaution as required under subsection 76.1 of CEPA 1999. Particular consideration was given to risk quotient analysis, persistence, bioaccumulation potential, toxicity, sources and fate in the environment.

Based on the information available for D4, this substance has been determined to be not persistent in water, but presents some bioaccumulative potential in aquatic organisms. A quantitative risk quotient evaluation of exposure and of ecological effects was therefore conducted as part of the weight-of-evidence evaluation of D4's potential to cause harm.

In the aquatic compartment, experimental acute and chronic toxicity studies for D4 were critically reviewed and accepted. D4 exhibited 50% mortality to fish in a 14-day study at a concentration of 0.01 mg/L, but showed no effect at a concentration of 0.0044 mg/L in the fish 14-day study and a fish early-life stage test. An application factor of 50 was applied to the sub-

chronic $LC_{50}$ of 0.01mg/L to account for extrapolations needed to arrive at a field based long-term multi-species no effect level. The calculated predicted no effect concentration (PNEC) is therefore 0.0002 mg/L.

A risk quotient (RQ) analysis, integrating the level of exposure with a toxicity threshold, was performed for D4. In order to address the potential risk of D4 on a national scale in Canada, a distribution profiling risk quotients in water at multiple release sites where the substance can be released by industry or by consumers (i.e., sewage treatment plants) was determined. This type of analysis provides a line of evidence for the risk assessment of a substance when the full range of geographic locations of the industrial and consumer releases of the substance cannot be fully established.

Specifically, when a substance is used by a number of industry sectors but the actual facilities involved cannot be identified, the aquatic exposure can be estimated for all sites where facilities related to these sectors are located. In addition to this, information on potential releases from consumer use can be integrated into the calculations. A predicted environmental concentration (PEC) for the water compartment is determined based on the use quantities identified from the section 71 survey submissions and estimates of releases from individual industrial sites and from consumers. The receiving water is either a watercourse or a lake, and a dilution factor based on the size of the receiving water—up to a maximum of 10—is used to estimate the PEC. The risk quotient at each site is then determined for the water column. The distribution indicates not only the proportion or number of threshold-exceeding sites, but also the magnitude of the exceedence at each of these sites. Further details on the approach are provided in Environment Canada (2008b).

The consumer releases used a database of approximately 1000 municipal discharge sites accounting for about 2/3 of the Canadian population. The industrial release analysis was done for 61 sites relating to 87 industrial facilities identified by NAICS code as possible users of D4. Under these scenarios, a total of 249 (~23.4%) of all evaluated municipal discharge sites across Canada showed a risk to aquatic organisms, with RQs exceeding 1 (Figure 1). The equation and inputs used to calculate the PEC in the receiving watercourses are described in Environment Canada (2008c).

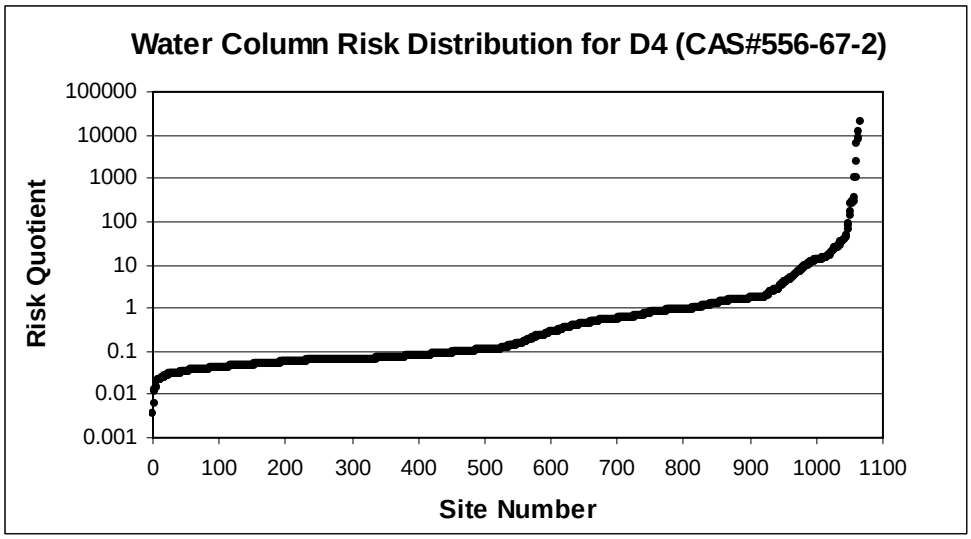



**Figure 1 – Aquatic Risk Distribution for D4 (CAS#556-67-2)**

The $\log K_{ow}$ for D4 (6.5) is in the range where bioavailability to pelagic and benthic biota is not significantly reduced and would not be considered "super-hydrophobic". Appreciable bioconcentration observed in optimized laboratory tests and measurable tissue residue values from available field monitoring data also suggest that the potential for body burdens reaching critical internal levels may not be mitigated by low bioavailability. Although the majority of the acute and chronic data reviewed suggest no effects at water saturated levels of D4, limited data suggest that D4 could potentially be highly toxic to specific aquatic species at sensitive early-life stages.

D4 is imported into Canada in significant quantities. Its uses suggest that this chemical is released into the Canadian environment in a dispersive manner. D4 has also been determined to be persistent in air and sediment, and has the potential to bioaccumulate in biota. In light of these findings and the estimated risk of D4 being released from municipal wastewater, long-term environmental exposure to D4 is expected to potentially have adverse effects on aquatic organisms in certain Canadian environments.

Therefore, because the physical-chemical property, bioconcentration and ecotoxicity profiles for D4 provide a consensus basis for the weight of evidence, it can be reasonably concluded that D4 has the potential to cause ecological harm, particularly from long term exposures near discharge zones.

**Uncertainties in Evaluation of Ecological Risk**

D4 is imported into Canada at significant quantities. It is also one of the major components in CAS RN 69430-24-6. It is also present in PDMS at up to 3%. The Challenge to industry and other stakeholders issued by the Government of Canada (Canada 2007) did not survey CAS RN 69430-24-6 (cyclomethicone, the mixture) or PDMS. Even though there is evidence that some

companies did report individual cVMS in the mixture under the survey, the quantities of these substances imported into Canada and their uses in 2006 are not completely known, and their releases into the Canadian environment are not considered fully in this screen assessment report.

Since no release information from industrial operations was available for the risk distribution analysis, it is assumed that releases to wastewater were uniformly distributed among 64 industrial sites evaluated. In reality, certain industrial sites may use higher quantities of D4 than others, resulting in higher releases to the municipal discharging sites associated with these industrial sites and therefore a higher risk than predicted. The distribution concentrations in the analysis applied instantaneous dilution of the effluent from sewage treatment plants (STP) into the receiving water. However, under realistic environmental conditions, the dilution may be gradual over a certain distance from the discharge point and the area near the discharge point of an STP may present a higher risk than predicted.

Sediment is an important media of concern for D4. The sediment degradation studies are not without uncertainties. Extrapolation of half-lives at low temperature in sediment based on hydrolysis data may also contribute to the overall uncertainty in sediment persistence. Limited data for bioaccumulation potential in this compartment also contributes to the overall ecological assessment uncertainty.

The available bioconcentration data and biomagnification factor and sediment accumulation values for D4 are conflicting. There is a lack of field data on bioaccumulation potential via the food web and in non-aquatic organisms.

Environmental monitoring data in Canada and elsewhere are limited. Sampling and analytical methodologies are still developing. Sample contamination is a potential problem in environmental monitoring due to D4's widespread uses. Data on environmental concentrations of D4 in biota and surface water in Canada are lacking and few environmental concentrations have been reported outside of urban areas in Canada. Consequently, monitoring data from European countries have been presented in this report. However, monitoring has been identified as a key component in the Chemicals Management Plan in Canada and D4 is being considered for environmental monitoring under the Plan. Environmental monitoring will contribute to a better understanding of the environmental presence and "true" environmental accumulation potential of the substance in the environment.

## Potential to Cause Harm to Human Health

### Exposure Assessment

The data on levels of D4 found in environmental media including ambient air near and away from point sources, surface waters, sediments, sewage sludge and biota are described in this report in the section entitled "Ecological Exposure Assessment." Unpublished data from Canada include measurements taken of biogas at landfills (Cianciarelli 2007, unpublished results); air

near and away from point sources (personal communication, Environment Canada, Canadian Centre for Inland Waters, 2007 [unreferenced]); air, influent and effluent water at wastewater treatment plants (personal communication, Environment Canada, Canadian Centre for Inland Waters, 2007 [unreferenced]); and Great Lakes sediment (Powell and Kozerski 2007). Many analyses of volatile siloxanes have been confounded by sample contamination during collection and analysis, resulting in siloxanes being detected in blanks at levels comparable in some cases to those in samples taken near point sources. Results of extensive sampling and measurement of siloxanes in environmental media in Scandinavia have been published by the Nordic Council of Ministers and the Swedish Environmental Research Institute (Norden 2005, Kaj et al. 2005). A survey of volatile organic chemicals, including siloxanes, in residential air was conducted from 2002 to 2004 in homes in Syracuse, New York, U.S.A. (NYIEQ 2005). Data from these reports were considered reliable and were used to produce the upper-bounding estimates of exposure to siloxanes in air, water and soil by the general population in Canada.

The upper-bounding estimates of daily intake of D4 for six age groups in the Canadian population are shown in Appendix 1. The estimates of intake from environmental media and diet range from 43.6 µg/kg body weight/day (µg/kg-bw/day) for adults aged 60 years and older to 132.5 µg/kg-bw/day for children aged 6 months to 4 years. The most significant contribution to daily intake from environmental media is inhalation of indoor air, based on a study of approximately 130 homes in Syracuse, New York, in which D4 was detected in 15% of samples. The mean concentration of D4 in indoor air measured in homes in this study was 32.5 µg/m$^3$ and the maximum concentration was 249 µg/m$^3$ (NYIEQ 2005). To compare the estimated exposure by inhalation to the critical effect level for D4 via inhalation, a time-weighted average air concentration based on maximum concentrations of D4 in indoor and ambient air of 218 µg/m$^3$ was calculated based on occupancy of indoor and outdoor environments (Health Canada 1998).

Confidence in the upper-bounding estimate of exposure to D4 through environmental media and diet is moderate. No Canadian data were used, but data from studies in Scandinavia and the United States were available for ambient and indoor air, water and soil. The use of a regulatory limit for dimethylpolysiloxane in one quarter of dairy products and half of processed food may overestimate the dietary contribution to total exposure, but the estimated contribution from all food to exposure is less than one percent of the contribution from air.

Using ConsExpo 4.1, software developed to estimate exposure to consumer products, the potential absorbed dose of D4 through the use of personal care products was estimated for men and women that use skin care products, hair care products and antiperspirants (RIVM 2006). Manufacturers of personal care products are required to notify Health Canada of the concentration, within broad ranges, of siloxanes, including D4 and polydimethylcyclosiloxanes, termed cyclomethicone in personal care products.[1] Health Canada has been notified of approximately 100 cosmetic products that contain D4 and approximately 6000 cosmetic products that contain cyclomethicone or cyclomethicone mixtures (CNS 2007). Where only cyclomethicone and not D4 was listed as part of a product formulation, it was assumed that the cyclomethicone was composed of 100% D4. The data on the concentration of D4 in personal care products were obtained principally from the information provided by Canadian industry

[1] *Cosmetic Regulations* C.R.C., c. 869.

(Environment Canada 2007) and were supplemented by information from other sources noted in Appendix 2. Based on experimental observations that 88–95% of D4 evaporated from skin in 24 hours (Jovanovic et al. 2008, Zareba et al. 2002), it was assumed that 90% of a product left on the skin evaporated during use and was therefore not available for dermal absorption. A distinction was made between products that are washed off and those that are left on the body. Other assumptions are noted in Appendix 2.

The results of a sample calculation for the application of body lotion are shown in Appendix 2, and summaries of the estimated absorbed dose arising from the use of personal care products by women and men are shown in tables 1 and 2. For women, the estimated maximum plausible daily absorbed dose from the modelled personal care products, aggregated over inhalation, dermal and oral exposure, is 0.243 mg/kg-bw/day. For men, the estimated maximum plausible daily absorbed dose, aggregated over inhalation, dermal and oral exposure, is 0.041 mg/kg-bw/day. These estimates show that for the range of personal care products considered, the absorbed dose for women is much higher than for men, since women tend to use more products that are left on the skin. The use of personal care products by children was not modelled because of a lack of comprehensive product use pattern data for children.

An exposure assessment for use of D4, including personal care product uses, was submitted to the Government of Canada under the Challenge Program (SEHSC 2007d). The methodology is different from that shown in Appendix 2, tables 1 and 2, as a Monte Carlo probabilistic analysis was conducted and aggregate general population exposures from all sources (including personal care products) and routes (inhalation, dermal, ingestion) were derived. The contribution of the use of personal care products to total exposure via separate exposure routes (inhalation, dermal, oral) was characterized and then summed to arrive at an aggregated exposure estimate. Due to the fact that D4 and D6 were used as analogues to determine oral toxicity of D5, D5 is used here as a surrogate for validation of the D4 probabilistic exposure assessment. Thus, a probabilistic exposure assessment for use of D5 was also submitted to the Government of Canada under the Challenge Program (SEHSC 2008a). Independent review of the submitted probabilistic assessment showed that this assessment evaluated exposure to both user and non-user groups (see Appendix 4). The data were re-analyzed based on just user groups to allow comparison with the deterministic exposure assessment in this screening assessment. Based on user groups only, the probabilistic exposure values for adult females (most highly exposed adult group) were 10–16 times lower than the deterministic values shown for D5. Therefore, based on D5 used as an analogue to determine probabilistic exposure values for D4, it is expected that probabilistic exposure values for adult females (most highly exposed adult group) will be 10–6 times lower than the deterministic values shown in Appendix 2, Table 1. Note that due to the requirement for detailed analysis and validation of probabilistic exposure assessments, such assessments are normally outside the scope for conducting the exposure component of a screening assessment.

Based on user groups only in the D5 probabilistic exposure assessment, the exposure values for children aged 0–6 months (most highly exposed children's group) were in the range of 0.016–0.032 mg/kg bw/day (see Appendix 4). A comparison with a deterministic exposure assessment for children was not possible due to the lack of sufficient product use data required for modelling children's exposure in a deterministic exposure assessment. When the children's probabilistic exposure values are compared with the adult female deterministic exposure values, they are 5–10

times lower for D5. Therefore, based on D5 used as an analogue to determine probabilistic exposure values for D4, it is expected that if the children's probabilistic exposure values for D4 were compared to the adult female deterministic exposure values, they would be 5–10 times lower for D4.

Other types of consumer products such as surface coatings, caulking and cleaners were deemed to contribute significantly less to daily exposure through daily use and were not further considered in the modelling of daily dose through consumer exposure scenarios. Both personal care products and other consumer products such as surface coatings, caulking and cleaners contribute to the concentration of D4 in indoor and ambient air and thus to exposure by inhalation. The contribution of all consumer products to total exposure of non-occupationally exposed individuals is estimated via indoor air in the multi-media environmental exposure model discussed in the preceding text of this section.

A comparison of the estimated absorbed dose arising from the use of personal care products and the upper-bounding estimate of exposure arising from environmental media and diet can be made by converting the exposure estimate to an absorbed dose estimate. This is done using a figure of 12% for the absorbed dose by inhalation (Utell et al. 1998, SCCP 2005) and 52% for ingestion (Dow Corning 1998b). The ratio of absorbed dose estimated for women from the use of personal care products to the dose estimated to arise from environmental media and diet (Appendix 1, Table 1) is 243 µg/kg-bw/day to 6.24 µg/kg-bw/day, or 39:1. The ratio is considerably lower for adult men using personal care products, about 7:1.

Confidence in the estimate of absorbed dose of D4 through the use of personal care products is moderate to low. All estimates were made by the use of models and the use pattern data were not from Canadian studies. Responses to a notice published under section 71 of CEPA 1999 indicate that D5 was used more frequently than D4 in personal care products in Canada in 2006 (Environment Canada 2007). This is consistent with qualitative information that in the personal care products industry, D5 has largely replaced D4 in personal care formulations (Environment Canada 2007, SEHSC 2007a). Absorbed-dose estimates of D4 through the use of personal care products were made with the assumption that each modelled product contained D4 at the stated concentration. This approach may overestimate the absorbed dose.

**Health Effects Assessment**

Appendix 3 contains a summary of the available health effects information for octamethylcyclotetrasiloxane.

The European Commission has classified D4 as Category 3 for reproductive toxicity (possible risk of impaired fertility) (European Commission 2001, ESIS 2007). This classification was based on reproductive effects observed in rats following inhalation exposure, specifically that "inhalation exposure of female rats to D4 around the time of mating causes a dose-related reduction of numbers of corpora lutea, implantation sites and litter sizes. These effects occur in the absence of marked maternal toxicity" (European Commission 2006). Also, the Danish EPA

has identified impaired fertility as the critical effect for D4, based on the same rat inhalation studies (Lassen et al. 2005).

When female rats were exposed to D4 for 28 days prior to mating, throughout mating and until gestation day 19, at 3600 mg/m$^3$ (300 ppm) and above, there was a significant decrease in the number of corpora lutea. At higher doses—6100 mg/m$^3$ (500 ppm) and 8500 mg/m$^3$ (700 ppm)—there were significant decreases in the numbers of implantation sites and viable fetuses, as well as non-significant increases in early resorptions and post-implantation losses. Similar effects occurred when female rats were exposed to 8500 mg/m$^3$ (700 ppm) D4 during the "fertilization phase" from three days prior to mating, throughout mating, to gestation day 3. A reduced pregnancy rate occurred in rats exposed to 700 ppm D4 for 6 hours one day before mating (Meeks et al. 2007). The value of 3600 mg/m$^3$ is considered to be a critical effect level for reproductive inhalation exposure in this assessment.

At exposure levels of 6100 mg/m$^3$ (500 ppm) and above in a 2-generation reproductive toxicity study, there were decreases in the mean litter size and the number of pups born to the F0 and F1 rats, and in the number of litters born to the F1 generation. There were also several F0 females in the 6100 mg/m$^3$ (500 ppm) and 8500 mg/m$^3$ (700 ppm) treatment groups that had extended parturition and dystocia, in two cases resulting in death. At 8500 mg/m$^3$ (700 ppm), there was a decrease in the number of implantation sites in the F0 rats. At this concentration there was also an increase in the mean estrous cycle length and gestation time, and decreases in the mating and fertility indices in F1 rats (Siddiqui et al. 2007).

No significant changes were observed in any reproductive parameters when female rats were exposed to 8500 mg/m$^3$ (700 ppm) D4 only during the "ovarian phase," (daily exposure for 28 days, then 3 days untreated, prior to mating); the "implantation phase" (daily exposure on gestation days 2 to 5); "post-mating" (daily exposure on gestation days 0 to 2); or following single 6-hour exposures on days 1, 2, 3 or 4 before mating or on gestation day 0, 1 or 2 (Meeks et al. 2007).

In an oral range-finding developmental toxicity study in rabbits, increased spontaneous abortions occurred at 500 mg/kg-bw/day and above, and increased post-implantation losses and decreased number of live fetuses were observed at 1000 mg/kg-bw/day. These effects were likely secondary to maternal toxicity, which was observed at 50 mg/kg-bw/day and above. No teratogenicity was observed in this study or in inhalation developmental toxicity studies in rats and rabbits (IRDC 1993a, 1993b, 1993c; GSPA 1991).

In a combined chronic/carcinogenicity inhalation study of D4 in male and female rats for up to 2 years, uterine (endometrial) adenomas and hyperplasia were observed at the highest dose level of 8500 mg/m$^3$ (700 ppm) (Dow Corning 2004). Although the Silicones Environmental, Health and Safety Council (SEHSC 2007d) argued that the endometrial adenomas and hyperplasia are not relevant to humans, this position has not been supported to date by international reviews due to lack of a thorough mode-of-action analysis. An increased incidence of mononuclear cell leukemia (MCL) was also observed in control and treated male rats. However, this tumour type is unique to rats and is common only in F344 rats, and the relevance to humans is unknown

(Caldwell 1999). There was no evidence of treatment-related genotoxicity in a wide range of *in vitro* and *in vivo* assays (see Appendix 3).

Studies on D4 in rats identified the liver as the most sensitive target organ. The lowest-observed-effect level (LOEL) for oral exposure was 5 mg/kg-bw/day based on increased liver enzymes (PROD, CYP2B1/2, CYP3A1/2) in two short-term gavage studies (Zhang et al. 2000, Falany and Li 2005). At higher test doses (≥20 mg/kg-bw/day) in short-term oral studies, relative liver weights were significantly increased (Zhang et al. 2000, Falany and Li 2005, Dow Corning 1990, 1997c). Although increased relative liver weights were observed only in female rats at 20 mg/kg-bw/day and higher (Zhang et al. 2000), increased relative liver weights were observed at 25 mg/kg-bw/day and higher in both sexes of rats in a 14-day oral study (Dow Corning 1990). Liver effects (accentuated lobular pattern of liver) were also observed in a 14-day oral rabbit study at 1000 mg/kg-bw/day (Dow Corning 1992). In addition, decreased fetal body weights and decreased relative liver weights in rat fetuses were observed when pregnant rats were dosed at 100 mg/kg-bw/day in 8-day studies (Falany and Li 2005), and in adult rats, decreased body weights and reduced thymus size were observed at doses of 500 mg/kg-bw/day and higher (Dow Corning 1992, IRDC 1993a).

Both relative and/or absolute liver weights were increased in short-term and long term inhalation studies as shown in Appendix 3. In some studies, these increases were preceded by induction of liver cell enzymes and/or cell proliferation at lower doses. It appeared that the liver weight increases may be associated with centrilobular hypertrophy of hepatocytes in 700-ppm male rats in the 6-month study (Dow Corning 2004). In the inhalation reproduction study in rats, hepatocyte hypertrophy increased in F1 females at 6100 and 8500 mg/m$^3$ and in F1 males at 8500 mg/m$^3$ and pigment in the liver and bile duct hyperplasia increased in F1 males at 8500 mg/m$^3$. The Scientific Committee on Consumer Products (SCCP 2005) concluded that the liver weight increase with centrilobular hepatocyte hypertrophy should be attributed to a phenobarbital-like effect, which induces rat hepatic cytochrome P450 enzymes, is reversible (upon cessation of exposure), and is not associated with overt hepatotoxicity. They also argued that the mild enzyme induction is considered to be an adaptive response to xenobiotics. Zhang et al. (2000) noted an increased induction of the liver enzyme, CYP3A1/2, by D4 that was greater than the induction caused by phenobarbital in a 4-day oral rat study. They concluded that although similar to a phenobarbital type of induction caused by the CYP2B enzyme series, the results suggest that there may be important mechanistic differences in the induction caused by D4. However, Falany and Li (2005) also noted an increased induction of the liver enzyme, CYP3A1/2, by D4 in 8-day rat studies but suggested that this was part of the phenobarbital-type induction due to related induction of the CYP2B and PROD enzymes. Consequently, it was not considered appropriate to determine adverse effect levels based on enzyme induction alone.

It is uncertain whether liver weight increases due to treatment with D4 are adaptive or adverse, and increases in liver weight following administration of D4 are therefore considered together with effects in other organ systems observed at similar doses/concentrations of D4.

Several studies have investigated the estrogenic and androgenic potential of D4. In an uterotrophic assay, octamethylcyclotetrasiloxane increased uterine weight and uterine epithelial cell height (up to 30 µm) at doses of 250 mg/kg-bw/day and above in rats (McKim et al. 2001a).

McKim et al. (2001a) concluded that octamethylcyclotetrasiloxane showed weak estrogenic and antiestrogenic activity in this assay. Studies conducted by Quinn et al. (2007a) in rats exposed by inhalation to D4, in receptor-binding studies and a luciferase reporter gene assay also showed weak estrogenic activity that is dose-dependent. In mice, serum estradiol levels decreased at oral doses of 100 mg/kg-bw/day and above (7-day studies); in ovariectomized mice, uterine weight was increased at 250 mg/kg-bw/day and up, and uterine peroxidase activity was increased at 1000 mg/kg-bw/day (3-day studies) (He et al. 2003). As stated above, decreased body weights and relative liver weights were observed at 100 mg/kg-bw/day in fetuses in 8-day oral studies of pregnant rats. D4 did not result in any increase in reproductive organ weights following inhalation exposure for 10 days in male rats at 8500 mg/m$^3$, thus indicating negative androgenic potential (Quinn et al. 2007a, 2007b). Based on the 7-day oral studies in mice and the 8-day oral studies in rats, the value of 100 mg/kg-bw/day is considered to be a critical effect level for repeated-dose oral exposure in this assessment.

The lowest-observed-effect concentration (LOEC) for inhalation exposure was 85 mg/m$^3$ (7 ppm), based on statistically significant increases in hepatic CYP2B1/2 and liver cell proliferation in a 5-day study in the rat (Dow Corning 1999, 2002; McKim et al. 2001b). At higher doses— ≥ 240 mg/m$^3$ (≥ 20 ppm)—in short- and long-term studies, additional effects included increased liver weight; increased kidney weight; nephropathy; reversible changes in organ weights (uterus, pituitary, adrenal, thymus, lung and ovary); and histopathological changes in the lung (increased focal alveolar histiocytosis) and female reproductive tract. No histopathological changes in the liver, kidney or pituitary were observed (Dow Corning1999, 2002, 2004; McKim et al. 1998, 2001b; Klykken et al. 1999; Burns-Naas et al. 2002). In a 3-month inhalation study in rats, a LOEC of 420 mg/m$^3$ (35 ppm) was determined based on increased absolute (20%) and relative (22%) liver weights, increased absolute and relative (17% increase) adrenal weights and decreased absolute and relative (17% decrease) thymus weights in females and alveolar macrophage foci and chronic interstitial inflammation of lung in both sexes (Burns-Naas et al. 2002, Dow Corning 1995b). A LOEC of 360 mg/m$^3$ (30 ppm) was determined in a 6-month rat study and a LOEC of 1800 mg/m$^3$ (150 ppm) was determined in 24-month rat study based on increased liver weight in both studies (Dow Corning 2004). The value of 420 mg/m$^3$ is considered to be a critical effect level for repeated-dose inhalation exposure in this assessment.

There were few data on toxicity of D4 in humans. Human volunteers (8 males and 4 females) exposed to 10 ppm of D4 (120 mg/m³) vapour for one hour via the mouth in a double-blind, randomized study showed no changes in lung function. The blood clearance was non-linear, with an elimination half-life of 330 min. The deposition of D4 was also measured with nasal and mouth breathing at resting ventilations in another 8 subjects. The overall average D4 absorption was 12% (Utell et al. 1998). In another study, an additional 6 human volunteers were exposed to 10 ppm of D4 (120 mg/m³) vapour for one hour via the mouth during alternating periods of rest and exercise; 13% of the absorbed dose was eliminated by exhalation 30 minutes after exposure, and blood concentrations of D4 decreased rapidly due to exhalation and metabolism (16% of absorbed dose in plasma 1 day after exposure). Human volunteers (number and sex not stated) exposed orally to 12 mg/day of D4 for 14 days in a double-blind, placebo-controlled crossover study did not show any immunotoxic or pro-inflammatory adjuvant effect (Dow Corning 1998c).

Based on validated studies in human skin, the SCCP (2005) suggested that the upper limit of dermal absorption is 0.94% of the applied dose of D4.

The confidence in the toxicity database is moderate to high, as there was sufficient information to address effects that may be of concern and identify critical endpoints based on oral and inhalation exposures, as well as available relevant supporting information. However, there was a lack of dermal and sometimes oral studies for some endpoints (subchronic, chronic toxicity/carcinogenicity, reproductive and developmental studies).

Although a thorough analysis of the mode of action of octamethylcyclotetrasiloxane is beyond the scope of this screening level assessment, it is recognized that an estrogenic effect or an indirect effect may contribute to the reproductive toxicity of octamethylcyclotetrasiloxane (Lassen et al. 2005). The reproductive toxicity of D4 was associated with inhibition of luteinizing hormone release in rats, and the relevance to humans of this mechanism is an area of uncertainty, as differing opinions have been expressed by SCCP (2005), SEHSC (2007d) and the European Commission (2006, 2007).

**Characterization of Risk to Human Health**

Based principally on the weight-of-evidence assessments of the European Commission and the Danish EPA, an important effect of D4 exposure is impaired fertility. However, the Danish EPA also identified the liver as a target organ for D4 exposures. Although lower effect levels were determined in other repeated-dose studies (85 $mg/m^3$ in a 5-day rat study, 360 $mg/m^3$ in a 6-month rat study), the effects observed (increased liver weight, liver enzyme induction) were not considered to be adverse due to evidence for reversibility of the liver weight changes in rats, which were not associated with other signs of hepatotoxicity. Based on several effects including increased liver weights, increased adrenal weights, decreased thymus weights and alveolar macrophage foci and chronic interstitial inflammation of the lung in a 3-month rat inhalation study, the critical effect level for repeated-dose toxicity is considered to be 420 $mg/m^3$ via inhalation. This level is also protective of reproductive effects, as such effects occurred at much higher doses in rats (≥3600 mg/kg-bw/day). Thus, comparison of the critical effect level for repeated-dose effects via inhalation (420 $mg/m^3$) and the conservative upper-bounding exposure estimate via inhalation for octamethylcyclotetrasiloxane, 249 $\mu g/m^3$, results in a margin of exposure of approximately 1700. Thus, the margins of exposure for repeated-dose effects and exposure via environmental media to the general population are considered to be adequate to account for uncertainties in the databases on exposure and effects. Margins of exposure based on consumer products are discussed below in the context of combined inhalation, dermal and oral exposures.

Although the focus of the assessment by the European Commission was inhalation, the Danish EPA assessment did not distinguish between exposure routes. Thus, it is considered prudent to establish a critical effect level for oral exposure, as a limited amount of oral toxicity data was available. As stated above, the critical effect level for repeated-dose toxicity is considered to be 100 mg/kg-bw/day via the oral route. This is based on decreased serum estradiol in the 7-day

mouse studies and decreased body weights and relative liver weights in fetuses in 8-day rat studies (D4 administered to pregnant females).

Comparison of the critical effect dose level for repeated dosing via the oral route (100 mg/kg-bw/day) and the upper-bounding estimate of daily intake of octamethylcyclotetrasiloxane by the general population in Canada results in a margin of exposure of approximately 5800. This is based on adjusting the inhalation contribution to daily intake by an inhalation absorption value of 12%, resulting in a systemic exposure of 17.3 µg/kg-bw/day.

The apparent intake dose of 0.25 mg/kg-bw/day from personal care products which incorporates absorption factors for dermal, inhalation and oral exposure (Table 1, Appendix 2) was corrected by applying the reciprocals of the oral factors to calculate the equivalent systemic dose of 0.30 mg/kg-bw/day. Using this calculated upper-bounding estimate of 0.30 mg/kg-bw/day, a comparison with the critical effect dose level for repeated dosing via the oral route (100 mg/kg-bw/day) resulted in a margin of exposure of approximately 330 for personal care product scenarios. However, it is considered that the exposure estimates presented above are overestimates of actual exposure based on a submitted probabilistic assessment and information indicating that the percentage of personal care products containing D4 on the Canadian market may be lower than assumed in deriving exposure estimates. Based on values derived from an independent review of the probabilistic exposure assessment for D5, which is considered to be a surrogate for the D4 probabilistic exposure assessment, it appears that the margin of exposure from use of personal care products would be at least 10 times higher for adults and at least 5 times higher for children from that shown above (i.e. > 1500). On the basis of the above considerations, including consideration for the extent of its database, D4 is considered not to meet the criteria under paragraph 64(c) of CEPA 1999.

**Uncertainties in Evaluation of Risk to Human Health**

The scope of this screening assessment does not take into consideration a full analysis of the mechanism of action of octamethylcyclotetrasiloxane (D4), and it does not take into account possible differences between humans and experimental species in sensitivity to effects induced by this substance. There is uncertainty surrounding the mechanism of reproductive toxicity as well as the mechanism of action resulting in liver effects following exposure via the inhalation or oral routes. Also, due to a lack of dermal studies for some endpoints, there is uncertainty regarding route-specific effects following dermal administration.

Although physiologically based pharmacokinetic modelling of inhalation absorption data (Reddy et al. 2003) and dermal absorption data (Reddy et al. 2007) have been published, the results of such modelling is considered beyond the scope of a screening assessment and thus, only experimental data on absorption were used in this assessment.

There is uncertainty regarding the estimation of exposure and systemic dose because of the use of modelling and a lack of Canadian data. There is uncertainty associated with the use of models and the choice of variables related to the use of consumer products including quantity and frequency of use, absorbed fraction, and environmental parameters.

The cumulative exposures of the cyclosiloxanes in polydimethylsiloxanes (PDMS) are not considered in this assessment. However, D5 and D6 are considered in separate assessments.

## Conclusion

Based on the information presented in this screening assessment on the potential of D4 to cause ecological harm, it is concluded that octamethylcyclotetrasiloxane is entering or may be entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity.

Based on the available information on its potential to cause harm to human health, it is concluded that octamethylcyclotetrasiloxane is not entering the environment in a quantity or concentration or under conditions that constitute or may constitute a danger in Canada to human life or health.

It is therefore concluded that octamethylcyclotetrasiloxane meets the definition of toxic as set out in paragraph 64a of CEPA 1999. It is also concluded that octamethylcyclotetrasiloxane meets the criteria for persistence as set out in the *Persistence and Bioaccumulation Regulations*. However, it is not possible to conclude that octamethylcyclotetrasiloxane meets the criterion for bioaccumulation, considering the conflicting evidence presented in this screening assessment report.

The conclusion in this screening assessment is based on the available information at this time and acknowledges that there are uncertainties associated with this assessment. Research on cVMS is currently being conducted to help address these uncertainties, but some of this research has not been completed at this time. In the context of the Challenge program, any new information provided after the final screening assessment may be considered during the risk management phase.

Monitoring has also been identified as a key component in the Chemicals Management Plan in Canada and D4 is being considered for environmental monitoring under the Plan. Field level data will contribute to a better understanding of the distribution of D4 in the environment and its bioaccumulation potential in relevant food webs.

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# Appendices

## Appendix 1

### Table 1: Upper-bounding estimates of daily intake of D4 by the general population in Canada

| Route of exposure | Estimated intake (µg/kg-bw per day) of D4 by various age groups | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0–6 months[1] | | | 0.5–4 years[5] | 5–11 years[6] | 12–19 years[7] | 20–59 years[8] | 60+ years[9] |
| | Breast fed[2] | Formula fed[3] | Fed solid food[4] | | | | | |
| Ambient air[10] | 0.08 | | | 0.18 | 0.14 | 0.08 | 0.07 | 0.06 |
| Indoor air[11] | 61.01 | | | 130.73 | 101.91 | 57.95 | 49.78 | 43.27 |
| Drinking water[12] | 0.99 | .01 | .004 | .004 | .003 | .002 | .002 | .002 |
| Food and beverages[13] | | | 2.97 | 1.62 | 0.91 | 0.49 | 0.32 | 0.29 |
| Soil[14] | <.001 | | | <.001 | <.001 | <.001 | <.001 | <.001 |
| Total intake | 62.08 | 61.1 | 64.06 | 132.53 | 102.96 | 58.53 | 50.17 | 43.62 |

1 Assumed to weigh 7.5 kg, to breathe 2.1 $m^3$ of air per day, to drink 0.8 L of water per day (formula fed) or 0.3 L/day (fed solid food) and to ingest 30 mg of soil per day (Health Canada 1998).

2 The highest concentration of D4 detected in human breast milk was10 µg/L in Sweden (Kaj et al. 2005). Breast-fed children 0–6 months of age are assumed to have an intake rate of 0.75 kg of breast milk per day (Health Canada 1998).

3 For exclusively formula-fed infants, intake of water is only that required to reconstitute formula. No data on detectable concentrations of D4 in drinking water were located. No data on concentrations of D4 in formula or baby food were identified for Canada. Approximately 50% of infants are introduced to solid foods by 4 months of age and 90% by 6 months of age (NHW 1990,).

4 The dietary intake is based on consumption of 0.3 litres of water and up to 1.18 kg of food daily. This intake pattern is presented as a hypothetical extreme case and does not reflect recommended infant feeding practice.

5 Assumed to weigh 15.5 kg, to breathe 9.3 $m^3$ of air per day, to drink 0.7 L of water per day and to ingest 100 mg of soil per day (Health Canada 1998).

6 Assumed to weigh 31.0 kg, to breathe 14.5 $m^3$ of air per day, to drink 1.1 L of water per day and to ingest 65 mg of soil per day (Health Canada 1998).

7 Assumed to weigh 59.4 kg, to breathe 15.8 $m^3$ of air per day, to drink 1.2 L of water per day and to ingest 30 mg of soil per day (Health Canada 1998).

8 Assumed to weigh 70.9 kg, to breathe 16.2 $m^3$ of air per day, to drink 1.5 L of water per day and to ingest 30 mg of soil per day (Health Canada 1998).

9 Assumed to weigh 72.0 kg, to breathe 14.3 $m^3$ of air per day, to drink 1.6 L of water per day

and to ingest 30 mg of soil per day (Health Canada 1998).

[10] D4 has been measured in ambient air near point sources in Canada, the United States, Europe and Asia. The highest measured concentration not near a point source, 2.4 μg/m$^3$ in Sepstrup Sande, Denmark, was used for the level of D4 in ambient air (Norden 2005). Canadians are assumed to spend 3 h per day outside (Health Canada 1998).

[11] D4 was detected in 15% of about 130 homes in Syracuse, New York between 2002 and 2004. The maximum concentration of D4 measured was 20.56 ppb, or 249 μg/m$^3$ (NYIEQ 2005). The data set considered includes a survey of bedrooms in homes in Sweden in which D4 was detected in 18% of samples and at a maximum concentration of 51.2 μg/m$^3$ (Kaj et al. 2005). Canadians are assumed to spend 21 h per day inside (Health Canada 1998).

[12] No data on levels of D4 in Canadian drinking water were identified. D4 was not detected in two samples of surface water away from point sources in Norway. The higher limit of detection of 0.09 μg/L was used (Norden 2005).

[13] No data were identified for the concentration of D4 in foods in Canada. The concentration of D4 in flounder filets from Norwegian waters was reported to be 1.9 ng/g on a wet-weight basis (NILU 2007). The maximum concentration of DMPS (CAS RN 9006-65-9, dimethylpolysiloxane) in certain processed food is limited by regulation to10 ppm.* A value of 1% D4 in DMPS, or 0.1 ppm in certain processed foods was assumed and it was further assumed that half of processed food and one quarter of dairy products are treated with antifoaming agents containing D4. The probable daily intake of D4 from food packaging for an adult was estimated to be less than 0.2μg/kg-bw/day (as per email from Food Packaging and Incidental Additives Section, Health Products and Food Branch of Health Canada, dated Feb. 27, 2008 unreferenced). Amounts of foods consumed on a daily basis by each age group are described by Health Canada (Health Canada 1998).

[14] No Canadian data were available for D4 levels in soil. No D4 was detected in two soil samples from the Faroe Islands taken at an abandoned and an operating landfill. The higher limit of detection of 10 μg/kg was used (Norden 2005).

* *Food and Drug Regulations***,** Division 16. C.R.C., c. 870.

# Appendix 2

## Consumer Exposure Modelling

**Sample ConsExpo 4.1 Report**

**Product**

Body lotion – women – partitioning 90/10

**Compound**

| | | |
|---|---|---|
| Compound name | Octamethylcyclotetrasiloxane | |
| CAS RN | 556-67-2 | |
| molecular weight | 297 | g/mol |
| vapour pressure | 140 | Pascal |
| $K_{ow}$ | 6.5 | 10Log |

**General exposure data**

| | | |
|---|---|---|
| exposure frequency | 1.5 | 1/day |
| body weight | 69 | kilogram |

**Inhalation model: exposure to vapour – constant rate**

| | | |
|---|---|---|
| weight fraction compound | 0.185 | fraction |
| exposure duration | 12 | hour |
| room volume | 80 | $m^3$ |
| ventilation rate | 1 | 1/hr |
| applied amount | 7.2 | gram |
| release duration | 12 | hour |

**Uptake model: fraction**

| | | |
|---|---|---|
| uptake fraction | 0.12 | fraction |
| inhalation rate | 22 | $m^3$/day |

**Dermal model: direct dermal contact with product – instant application**

| | | |
|---|---|---|
| weight fraction compound | 0.185 | fraction |
| exposed area | 1.57E3 | $cm^2$ |
| applied amount | 0.8 | gram |

**Uptake model: fraction**

| | | |
|---|---|---|
| uptake fraction | 0.0094 | fraction |

## Output

**Inhalation (point estimates)**

| | | |
|---|---|---|
| inhalation mean event concentration | 1.27 | $mg/m^3$ |
| inhalation mean concentration on day of exposure | 0.953 | $mg/m^3$ |
| inhalation air concentration year average | 0.953 | $mg/m^3$/day |
| inhalation acute (internal) dose | 0.0243 | mg/kg |
| inhalation chronic (internal) dose | 0.0365 | mg/kg/day |

**Dermal: point estimates**

| | | |
|---|---|---|
| dermal load | 0.0943 | $mg/cm^2$ |
| dermal external dose | 2.14 | mg/kg |
| dermal acute (internal) dose | 0.0202 | mg/kg |
| dermal chronic (internal) dose | 0.0302 | mg/kg/day |

**Integrated (point estimates)**

| | | |
|---|---|---|
| total external dose | 2.35 | mg/kg |
| total acute dose (internal) | 0.0445 | mg/kg |
| total chronic dose (internal) | 0.0667 | mg/kg/day |

| Table 1 | D4 | | Systemic Dose by Exposure to Personal Care Products – 69-kg Woman | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Product | Amount per application grams | Authority | Frequency per day | Authority | Weight fraction D4 | Authority | Retention factor | Inhalation mg/kg-bw/day at 12% abs | Dermal mg/kg-bw/day at 0.94% abs | Oral mg/kg-bw/day at 52% abs | Total mg/kg-bw/day |
| | | | | | | | | | | | |
| antiperspirant solid | 0.8 | RIVM | 1 | Maxim | 0.049 | NMI | 1 | 0.00064 | 0.00053 | | |
| body lotion | 8 | RIVM | 1.5 | RIVM | 0.185 | Section 71 | 1 | 0.0365 | 0.0302 | | |
| sunscreen | 6.1 | RIVM | 0.2 | RIVM | 0.01 | NMI | 1 | 0 | 0.00016 | | |
| face moisturizer | 2.5 | RIVM | 2 | RIVM | 0.185 | Section 71 | 1 | 0.0405 | 0.0126 | | |
| face makeup | 0.8 | RIVM | 1 | RIVM | 0.185 | Section 71 | 1 | 0.00243 | 0.00202 | | |
| lipstick | 0.01 | Maxim | 4 | RIVM | 0.25 | Maxim | 1 | 0 | 0.00027 | 0.0603 | |
| hair spray | 6.8 | RIVM | 1.2 | RIVM | 0.3 | CNS | 0.1 | 0.0384 | 0.00333 | | |
| hair shampoo | 20 | RIVM | 0.7 | RIVM | 0.03 | CNS | 0.01 | 0 | 0.00006 | | |
| hair conditioner | 20 | RIVM | 0.3 | RIVM | 0.185 | Section 71 | 0.01 | 0 | 0.00015 | | |
| hair styling | 4.7 | Maxim | 0.6 | Maxim | 0.3 | CNS | 0.1 | 0.014 | 0.00123 | | |
| | | | | | | | | | | | |
| Totals | | | | | | | | 0.132 | 0.0506 | 0.0603 | 0.243 |

Consumer exposure modelling based on ConsExpo (RIVM 2006).
Basic assumptions:

Body weight 69 kg

Absorption by inhalation 12% (Utell et al. 1998, SCCP 2005); dermal absorption 0.94% (SCCP 2005); absorption by ingestion 52% (Dow Corning 1998b).

For products left on skin except lipstick, 10% of applied amount is available to be dermally absorbed, 90% evaporates

For lipstick, 20% is available for dermal absorption and 80% is available for absorption by ingestion.

Authorities:
- NMI: see in references NMI 2007
- RIVM: see in references RIVM 2006
- CNS: see in references CNS 2007
- Section 71: see in references Environment Canada 2007
- Maxim: see in references Maxim 1998

| Table 2 | D4 | | Systemic Dose by Exposure to Personal Care Products – 82.3-kg Man | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Product | Amount per application grams | Authority | Frequency per day | Authority | Weight fraction D4 | Authority | Retention factor | Inhalation mg/kg-bw/day at 12% abs | Dermal mg/kg-bw/day at 0.94% abs | Oral mg/kg-bw/day | Total mg/kg-bw/day |
| | | | | | | | | | | | |
| antiperspirant solid | 1.22 | Maxim | 1 | Estimate | 0.049 | NMI | 1 | 0.000825 | 0.000672 | | |
| body lotion | 3.5 | Maxim | 0.7 | RIVM | 0.185 | Section 71 | 1 | 0.0062 | 0.0052 | | |
| sunscreen | 6.1 | RIVM | 0.2 | RIVM | 0.01 | NMI | 1 | 0 | 0.000114 | | |
| shaving preparation | 2 | RIVM | 1 | RIVM | 0.1 | CNS | 0.01 | 0 | 0.000228 | | |
| after shave lotion | 1.2 | RIVM | 1 | RIVM | 0.1 | CNS | 1 | 0.00168 | 0.00228 | | |
| hair shampoo | 20 | RIVM | 0.7 | RIVM | 0.03 | CNS | 0.01 | 0 | 0.00048 | | |
| hair conditioner | 20 | RIVM | 0.3 | RIVM | 0.185 | Section 71 | 0.01 | 0.00144 | 0.00013 | | |
| hair pomade | 4.7 | Maxim | 0.6 | Maxim | 0.3 | CNS | 0.1 | 0.0116 | 0.0103 | | |
| | | | | | | | | | | | |
| Totals | | | | | | | | 0.0217 | 0.0194 | | 0.0411 |

Consumer exposure modelling based on ConsExpo (RIVM 2006).
Basic assumptions:

Body weight 82.3 kg
Absorption by inhalation 12% (Utell et al. 1998, SCCP 2005); Dermal absorption 0.94% (SCCP 2005)
For products left on skin 10% of applied amount is available to be dermally absorbed, 90% evaporates

Authorities:
NMI: see in references NMI 2007
RIVM: see in references RIVM 2006
CNS: see in references CNS 2007
Section 71: see in references Canada 2007
Maxim: see in references Maxim 1998

## Appendix 3

## Summary of Health Effects Information for Octamethylcyclotetrasiloxane

| Endpoint | Lowest effect levels[1]/Results |
|---|---|
| Acute toxicity | **Lowest oral $LD_{50}$** (rat) = 1540 mg/kg-bw in rat (strain not stated) (Union Carbide Co. 1993).<br>**Lowest dermal $LD_{50}$** (rabbit) = 759 mg/kg-bw [converted from 794 µL/kg] in rabbit (strain not stated) (Union Carbide Co. 1993)[2].<br>**Lowest inhalation $LC_{50}$:** 36 000 mg/m$^3$ =2975 ppm in Fischer rats for single 4-hour nose-only inhalation exposure (Dow Corning 1994).<br><br>Other studies: Several cited in IUCLID 2000 and SEHSC 2007d. |
| Short-term repeated-dose toxicity | **Lowest-observed-effect level (LOEL) – oral:** 5 mg/kg-bw/day based on increased liver enzymes CYP2B1/2 and PROD in Sprague Dawley (SD) rats treated by oral gavage with 0, 5, 20 or 100 mg/kg-bw/day for 4 days. At 20 mg/kg-bw/day, effects observed were increased induction of liver enzyme, CYP3A1/2 and increased relative liver weights in females only and increased ethoxyresorufin-O-deethylase (EROD) activity in both sexes (but CYP1A1/2 level did not increase) (significant CYP3A1/2 induction and non-significant increase in relative liver weights in males only at 100 mg/kg-bw/day) (Zhang et al. 2000).<br>And 5 mg/kg-bw/day based on induction of CYP2B1/2 immunoreactive protein in young and mature females, induction of PROD in mature females, and induction of CYP3A1/2 immunoreactive protein in mature female in young, pregnant and mature female SD rats treated by oral gavage with 0, 5, 20 or 100 mg/kg-bw/day for 8 days. At 100 mg/kg-bw/day, additional effects included decreased fetal body weights and liver weight / body weight ratio in fetuses (liver weight / body weight ratio was increased by 20% in mature rats) (Falany and Li 2005).<br><br>Other oral studies: Dow Corning 1990, 1992, 1997d.<br><br>**Lowest-observed-effect concentration (LOEC) – inhalation:** 85 mg/m$^3$ = 7 ppm based on liver cell proliferation and induction of liver enzyme CYP2B1/2 in Fischer 344 (F344) rats exposed by whole-body inhalation to 0, 85, 360, 850, 1800, 3600 or 8500 mg/m$^3$ (0, 7, 30, 70, 150, 300 or 700 ppm) for 5 days (Dow Corning 1999, 2002; McKim et al. 2001b).<br>Other inhalation studies: Dow Corning 1988a, 1998b, 1989a, 1995a; Klykken et al. 1999.<br><br>**Highest no-observed-effect level (NOEL) – dermal:** No effects observed at 960 mg/kg-bw/day in a 3-week dermal study in New Zealand White rabbits exposed to unoccluded conditions (5 days/week) at 96, 190/288[3] or 960 mg/kg-bw/day. (Body weights, clinical signs, skin changes and clinical chemistry parameters measured during the study. At post-mortem, major organs were weighed and histology of the control and high-dose group was conducted.) (Bayer 1988).<br>No other dermal studies identified. |

[2] This value was checked and appears to be correct. However, we note the apparent inconsistency between an oral $LD_{50}$ value of 759 mg/kg-bw in rabbits and the dermal NOEL of 960 mg/kg-bw/day in the 3-week dermal rabbit study.

[3] IUCLID (2000) and SCCP (2005) state the mid-dose to be 190 mg/kg-bw/day whereas SEHSC (2007d) states the mid-dose to be 280 mg/kg-bw/day.

| Endpoint | Lowest effect levels[1]/Results |
|---|---|
| Subchronic toxicity | **Highest oral NOEL:** No effects in rats (strain not stated) or rabbits (strain not stated) treated at 500 mg/kg-bw/day (1% in diet) for 8 (rabbits) or 12 months (rats) (Dow Corning 1986).<br>No other oral studies identified.<br><br>**Lowest inhalation LOEC:** 360 mg/m$^3$ = 30 ppm based on increased absolute liver weight (percentage increase not stated) in males in F344 rats exposed by whole-body inhalation to 0, 120, 360, 1800 or 8500 mg/m$^3$ (0, 10, 30, 150 or 700 ppm) for 6 h/day, 5 days/wk for 6 months (Dow Corning 2004).<br>**Other LOEC:** 420 mg/m$^3$ based on alveolar macrophage foci and chronic interstitial inflammation of lung at this dose and higher in both sexes and in females, increased absolute (20%) and relative (22%) liver weights, increased absolute and relative (17% increase) adrenal weights and decreased absolute and relative (17% decrease) thymus weights in F344 rats exposed by nose-only inhalation for 6 h/day, 5 days/wk for 3 months to 0, 35, 122, 488 or 898 ppm (equal to 0, 420, 1480, 5910 or 10900 mg/m$^3$). Reversible increased liver weight in rats (percentage increase not stated) at 488 ppm and higher (Burns-Naas et al 2002, Dow Corning 1995b)<br>Other inhalation studies: Dow Corning 1989b, GSPA 1991.<br><br>No dermal studies identified. |
| Chronic toxicity / carcinogenicity | **Inhalation carcinogenicity bioassay in rats**: Increased endometrial adenomas at 8500 mg/m$^3$ (700 ppm) only, in F344 rats exposed by whole-body inhalation for 6 h/day, 5 days/wk for 2 years to 0, 120, 360, 1800 or 8500 mg/m$^3$ (0, 10, 30, 150 or 700 ppm ). Mononuclear cell leukemia (MCL) incidence higher than historical values in control and high-dose (8500 mg/m$^3$) males (Dow Corning 2004).<br>**Lowest inhalation non-neoplastic LOEC:** 1800 mg/m$^3$ = 150 ppm based on increased absolute and relative liver weight (percentage increase not stated) and increased absolute and relative kidney weight in female rats in the same 2-year rat study (Dow Corning 2004, Lee et al. 2005).<br><br>No oral or dermal studies identified. |
| Developmental toxicity | **Lowest oral LOEC for embryofetal toxicity:** 500 mg/kg-bw/day based on increased spontaneous abortions at this dose and above in pregnant New Zealand White (NZW) rabbits treated by oral gavage during gestation days 7–19 to 0, 50, 100, 500 or 1000 mg/kg-bw/day. There were also increased post-implantation losses and decreased number of live fetuses at 1000 mg/kg-bw/day. Maternal toxicity (decreased food intake and body weight gain) was observed at doses of 50 mg/kg-bw/day and higher in this study, and the developmental effects were likely secondary rather than direct effects. No teratogenicity was observed in this study (IRDC 1993a).<br>No other oral studies identified.<br><br>**Inhalation:** No teratogenicity or embryofetal toxicity was observed in inhalation studies at exposures of up to at 8500 mg/m$^3$ (700 ppm) in SD rats exposed to 0, 1200, 3600 or 8500 mg/m$^3$ (0, 100, 300 or 700 ppm) or up to 6100 mg/m$^3$ (500 ppm) in NZW rabbits exposed to 0, 1200, 3600 or 6100 mg/m$^3$ (0, 100, 300 or 500 ppm) by whole-body inhalation for 6 h/day during gestation days 6–15 (rats) or 6–18 (rabbits) (IRDC 1993b, 1993c).<br>Other inhalation studies: GSPA 1993a, 1993b<br><br>No dermal studies identified. |
| Reproductive toxicity | **Inhalation LOEC for reproductive toxicity:** 3600mg/m$^3$ (300 ppm) based on decreased number of corpora lutea in a single-generation study (Meeks et al. 2007). |

| Endpoint | Lowest effect levels[1]/Results |
|---|---|
| | In several studies, when female SD rats were exposed to octamethylcyclotetrasiloxane (D4) by inhalation, effects on reproductive parameters were observed: decreased number of corpora lutea, implantation sites, number of fetuses and litter size; increased pre- and post-implantation losses; decreased mating and fertility indices; and extended parturition. In a 2-generation study, in which SD rats were exposed to D4 by whole-body inhalation for 6 h/day from 70 days prior to mating through to gestation day 20 and lactation day 5 to termination (F0 generation males and females) and from lactation day 22 (weaning) through to mating to gestation day 20 (F1 females) at 0, 850, 3600, 6100 or 8500 mg/m$^3$ (0, 70, 300, 500 or 700 ppm), some additional effects were observed in the F1 generation: estrous cycle variations, histopathological changes to the mammary glands (ductal/acinar proliferation and evidence of secretion) and ovaries (anovulatory) (no effects in uterus), and increased pituitary weight. At 6100 mg/m$^3$ (500 ppm) and above, there were decreases in the mean litter size and the number of pups born to the F0 and F1 rats, and in the number of litters born to the F1 generation; several F0 females had extended parturition and dystocia, in two cases resulting in death. At 8500 mg/m$^3$ (700 ppm), there was a decrease in the number of implantation sites in the F0 rats. At this same dose there was also an increase in the mean estrous cycle length and gestation time, and decreases in the mating and fertility indices in F1 rats (Meeks et al. 2007, Siddiqui et al. 2007). No developmental related effects (anogenital distance, balanopreputial separation, vaginal patency) were observed in pups (Siddiqui et al. 2007).<br>**Inhalation LOEC for systemic toxicity:** 3600 mg/m$^3$ (300 ppm) based on increased relative liver weights in F0 and F1 males, increased absolute and relative liver weights in F0 females and increased relative kidney weights in F0 males in the 2-generation study (in F1 females, absolute and relative liver weights increased at 6100 mg/m$^3$ and absolute and relative kidney weights increased at 8500 mg/m$^3$) (Siddiqui et al. 2007).<br><br>Meeks et al. (2007) also conducted pre- and post-mating phase studies in which female SD rats were exposed to D4 by whole-body inhalation for 6 h/day for (i) 4th, 3rd, 2nd or 1st days prior to mating, 3–1 days prior to mating or 3 days prior to mating to gestation day 3 = premating phase or (ii) gestation days 0, 1 or 2 or gestation day 0–2 = post-mating phase. Main effects during the pre-mating phase were decreased food consumption and "effects on mean body weight gain," decreased number of corpora lutea and implantation sites, increased number of small implantation sites, and decreased mean uterine weight. During the post-mating phase the effects observed were decreased food consumption and mean body weight gain.<br><br>No effects on reproductive parameters were observed when male rats were exposed by inhalation at concentrations up to 8500 mg/m$^3$ (700 ppm) and mated with untreated females (Dow Corning 1997a, 1997b).<br>Other studies: Dow Corning 1996a, 1996b, 1997c, 1998a<br><br>**Positive in estrogenic activity**: D4 increased uterine weight in rats and mice and uterine epithelial cell height (up to 30 µm) in rats at oral doses of 250 to 1000 mg/kg-bw/day in immature SD and F344 rats and in B6C3F1 mice exposed for 3 or 4 days (McKim et al. 2001a, He et al. 2003). A dose-related reduction in serum estradiol from 100 to 1000 mg/kg-bw/day was observed in female B6C3F1 mice dosed for 7 days (He et al. 2003).<br>Inhalation studies with D4 showed increased wet or blotted uterine weights and uterine epithelial cell height (up to 33 µm) following exposure for 3 days in SD and F344 rats at a concentration of 8500 mg/m$^3$ (700 ppm) (Quinn et al. 2007a), as well as a decreased number of females that ovulated, and suppression of luteinizing hormone surge at this concentration in female SD rats (Quinn et al. 2007b).<br>**Negative in androgenic activity:** In Hershberger assay, D4 did not result in any increase in reproductive organ weights following inhalation exposure for 10 days in male F344 rats |

| Endpoint | Lowest effect levels[1]/Results |
|---|---|
| | at 8500 mg/m$^3$ (700 ppm) (Quinn et al. 2007a, 2007b). |
| Endocrine disruption *in vitro* | D4 showed binding potential to human estrogen receptor α (ERα) but not to estrogen receptor β (ERβ), and was positive in ERα reporter gene assay in a human epithelial cell line MCF-7. D4 showed no binding affinity to progesterone receptors (PRs), but was positive in PRβ reporter gene assay (Quinn et al. 2007a). |
| Genotoxicity and related endpoints: *in vivo* | **Chromosome aberrations:**<br>**Negative**: male, female rat; inhalation (8500 mg/m$^3$ (700 ppm), 6 hours/day, 5 days); bone marrow (Vergnes et al. 2000).<br><br>**Dominant lethal assay:**<br>**Negative**: rat; oral (100, 500, 1000 mg/kg-bw/day for 8 weeks) (Dow Corning 1982). |
| Genotoxicity and related endpoints: *in vitro* | **Mutagenicity:**<br>**Negative**: *Salmonella typhimurium* TA98, TA100, TA1535, TA1537, TA1538; with and without activation (Vergnes et al. 2000; Isquith et al. 1988).<br>**Negative**: mouse lymphoma L5178Y cells (TK locus); with and without activation (Isquith et al. 1988).<br>**Negative**: rat2λlacI fibroblasts (Felix et al. 1998).<br>**Negative**: *Saccharomyces cerevisiae* strain D4 (Isquith et al. 1988).<br><br>**Chromosome aberrations:**<br>**Negative**: Chinese hamster ovary (CHO) cells; with and without activation (Vergnes et al. 2000).<br>**Negative**: mouse lymphoma cells; without activation (Isquith et al. 1988).<br>**Positive**: mouse lymphoma cells; with activation, high dose only, no dose-response, cytotoxicity (Isquith et al. 1988).<br><br>**Sister chromatid exchange:**<br>**Negative**: CHO cells; with and without activation (Vergnes et al. 2000).<br>**Negative**: mouse lymphoma cells; with and without activation (Isquith et al. 1988).<br><br>**DNA damage:**<br>**Negative**: alkaline elution assay in mouse lymphoma cells; with and without activation (Isquith et al. 1988).<br>**Negative**: DNA repair assay in *Escherichia coli*; with and without activation (Isquith et al. 1988). |
| **Human studies** | **Lowest effect levels[1]/Results** |
| Acute toxicity | Human volunteers (8 males + 4 females) exposed to 10 ppm of D4 vapour (120 mg/m$^3$) for one hour via the mouth in a double-blind, randomized study showed no changes in lung function. The blood clearance was non-linear with an elimination half-life of 330 min. The deposition of D4 was also measured with nasal and mouth breathing at resting ventilations in another 8 subjects. The overall average D4 absorption was 12% (Utell et al. 1998). |
| Short-term repeated-dose toxicity | Human volunteers (number and sex not stated) exposed orally to 12 mg/day of D4 for 14 days in a double-blind, placebo-controlled crossover study did not show any immunotoxic or pro-inflammatory adjuvant effect (Dow Corning 1998c). |

[1] $LD_{50}$ = median lethal dose
$LC_{50}$ = median lethal concentration
LOEL = lowest-observed-effect level
LOEC = lowest-observed-effect concentration
NOEL = no-observed-effect level

## Appendix 4: Review of D5 Probabilistic Exposure Assessment

| | |
|---|---|
| **PROJECT** | D5 Probabilistic Exposure Assessment |
| **TASK** | Review D5 Probabilistic Exposure Assessment conducted by Silicones Environmental, Health and Safety Council (SEHSC) |
| **FOR** | Health Canada (Healthy Environments and Consumer Safety Branch) |
| **BY** | infoscientific, Henderson, Nevada, USA |
| **PERIOD** | August–September, 2008 |

### EXECUTIVE SUMMARY

A review of the D5 probabilistic exposure assessment submitted by SEHSC was done and comments to assist in preparing the screening assessment report for D5 is provided in this report.

"User Only" daily exposures were estimated based on a Monte Carlo analysis using Crystal Ball. Mean exposure and 90$^{th}$ percentile exposure summaries were generated for different subpopulations (children and adults).

For dermal and inhalation exposure routes, the current assessment resulted in higher exposures than the assessment done by SEHSC. The primary reason was the consideration of "user only" subpopulation in the current assessment compared to the "user" and "non-user" subpopulations considered in the SEHSC assessment. The dermal exposure route had higher exposures for both children and adults. Diaper cream, body lotion and sunscreen contributed to higher exposures in the dermal route; soothing vapour in the inhalation route and antifoam and fish in the ingestion route.

## INTRODUCTION

As a part of Canada's Chemicals Management Program, Decamethylcyclopentasiloxane (D5) has been identified by Health Canada as a material to be reviewed and considered in a screening level assessment.

SEHSC submitted information on D5 to assist Health Canada in preparing the screening assessment report for D5. The information provided included toxicity information not readily available in the literature and a comprehensive exposure assessment utilizing Monte Carlo analysis. The exposure assessment included information on the levels of D5 in different environmental media and on consumer product use patterns.

Health Canada contracted with infoscientific, USA to review the D5 probabilistic exposure assessment submitted by SEHSC and to provide comments to assist in preparing the screening assessment report for D5.

## DESCRIPTION

SEHSC's Monte Carlo-based probabilistic assessment for D5 included the following age-dependent and exposure-route-dependent scenarios:

- Children – dermal route: body lotion, conditioner (leave in), conditioner (rinse off), diaper cream, shampoo (2-in-1) soothing vapour, spray detangler, sunscreen
- Children – ingestion route: antifoam, baby bottle nipple, fish (general population), fish (subsistence population), human milk, leafy vegetables (greens), meat, milk, pacifier, root vegetables, sipper tube, soil, straws, water
- Children – ingestion route: OTC (over-the-counter) drugs
- Children – inhalation route: indoor air, outdoor air, soothing vapour
- Adults – dermal route: after shave, body lotion, conditioner (leave in), conditioner (rinse off), foundation, hair spray, mascara, moisturizer, nail care, roll-on antiperspirant, shampoo, solid antiperspirant, soothing vapour, sunscreen, under-eye cream
- Adults – ingestion route: antifoam, fish (general population), fish (subsistence population), leafy vegetables (greens), lipstick, meat, milk, root crops, soil, water
- Adults – ingestion route: OTC (over-the-counter) drugs
- Adults: inhalation route: indoor air, outdoor air, soothing vapour

Separate route-specific and total exposure estimates were made for the following subpopulations:

- Children: ages 0 to 6 months, breastfed
- Children: ages 0 to 6 months, non-breastfed
- Children: ages 0 to 6 months, males
- Children: ages 0 to 6 months, females
- Children: ages 7 to 11 months, breastfed
- Children: ages 7 to 11 months, non-breastfed
- Children: ages 1 to 2 years, breastfed
- Children: ages 1 to 2 years, non-breastfed
- Children: ages 2 to 4
- Children: ages 6 months to 4 years, males
- Children: ages 6 months to 4 years, females
- Children: ages 4 to 11 years, males
- Children: ages 4 to 11 years, females
- Adults: ages 12 to 19 years, males
- Adults: ages 12 to 19 years, females

- Adults: ages 20 to 59 years, males
- Adults: ages 20 to 59 years, females
- Adults: ages 60+ years, Males
- Adults: ages 60+ years, Females.

The following documents and data files were provided to assist with the review process:

- D5_Kids, an Excel file, compatible with Crystal Ball, that contained all the exposure calculations for children
- D5_Adults, an Excel file, compatible with Crystal Ball, that contained all the exposure calculations for adults
- UPDATED Final Submission for Health Canada – D5, a Word file that contains information related to toxicity and exposure for D5
- Attachment 1 – Exposure Assessment for D5, a Word file that is a report explaining the probabilistic exposure assessment, including inputs used and outputs generated

The following steps were taken during the process of reviewing the D5 probabilistic assessment submitted by SEHSC:

- reviewed documents provided by Health Canada
- identified product-based exposure scenarios, exposure pathways and exposure subpopulations
- used the Excel files provided by Health Canada (D5_Kids.xls and D5_Adults.xls; files created by SEHSC) as starting points
- assured the quality of Crystal Ball-based probabilistic calculations
- generated Crystal Ball-based probabilistic Monte Carlo outputs and compared them with those listed in documents submitted by SEHSC
- commented on the robustness of industry's (SEHSC) probabilistic assessment and recommended whether it should be considered further in the screening assessment for D5

It must be mentioned that the review process did not

- validate the list of scenarios that cover all D5 exposures to children and adults
- validate the input values used in the SEHSC assessment
- validate the sources of the input values

However, the review process did

- check cells designated as Crystal Ball Assumptions (check the assignment of distributional parameters for inputs)
- check cells designated as Crystal Ball Forecasts (check the assignment of results)
- check formulas for the different calculations

A few errors were detected in the calculations. All these errors, which appeared in the formula cells, were incorrect references to formula inputs (incorrect cell references were provided).

Each exposure scenario—dermal, ingestion, or inhalation—has two use-related parameters associated with it: frequency of use/occurrence (number of times per day) and percentage of population engaged in scenario. For the parameter " frequency of use/occurrence", the values used in the SEHSC assessment were also used in the current assessment, except when the value was less than 1.0; in this case, a value of 1.0 was assigned.

The SEHSC assessment relies heavily on the parameter "percentage of population engaged in scenario" to estimate exposures for the general population which includes users and non-users. The current assessment ignores this parameter completely. For example, in the case of a scenario where 20% of the population is engaged, in a probabilistic Crystal Ball run with 200 000 simulations, the SEHSC assessment will have

160 000 estimates with zero values and 40 000 estimates with values greater than zero. On the other hand, the current assessment will have 200 000 estimates with values greater than zero. As a result, both mean exposure estimates and 90$^{th}$ percentile exposure estimates generated by the current assessment will be greater than those generated by the SEHSC assessment. Conclusion: "user-only" exposures make a significant difference when comparing results generated by SEHSC and by infoscientific.

Exposure summary results were generated for 1) individual scenarios by specific exposure routes, 2) multiple scenarios by specific exposure routes (total exposure by specific exposure route) and 3) multiple scenarios aggregated over multiple routes (total exposure).

Total exposure within an exposure route is estimated by summing exposures for each scenario. Then total exposure across multiple exposure routes is estimated by summing exposures for each exposure route. Let us consider single Monte Carlo simulations within two separate probabilistic assessments: (1) a "user only" assessment (similar to the current assessment) and (2) a "user/non-user" assessment (similar to the SEHSC assessment).

In case (1), for each scenario, there is a finite probability that the individual represented in the simulation engages in that scenario. Thus, for multiple scenarios, the individual is involved only in a fraction of the scenarios and not all the scenarios considered. For those scenarios in which the individual engages, exposure estimates are generated. Total exposure is the sum of individual scenario exposures. This case can be extended to represent individuals in a general population.

By contrast, in case (2), for all scenarios, the probabilities for the individual represented in the simulation engaging in each equal 1.0 (100%). And, in this case, for multiple scenarios, the individual is involved in all the scenarios. Total exposure, which is the sum of individual scenario exposures, represents all the scenarios. The probability of an individual in a general population engaging in all the scenarios is unlikely.

Based on the above explanations for the two cases, in the current assessment, the "user only" summaries generated for individual scenarios are valid results. However, the summaries generated for total exposures, either within individual exposure routes or across exposure routes, are improbable and should be interpreted with caution. For total exposures, the estimates generated by SEHSC would be more applicable than the ones generated by the current assessment.

Adding exposures across exposure routes should be done after consideration of route-specific toxicological endpoints. If the route-specific toxicological endpoints are unequal, route-specific total exposures cannot be added without applying appropriate absorption/penetration factors and/or potency factors.

## EXPOSURE RESULTS AND DISCUSSION: CHILDREN

**Table 1. Children's mean exposures (based on 200 000 Crystal Ball simulations)**

| Mean exposures | | Ages 0–6 months | | 6 m – 4 yrs | | 4 yrs – 11 yrs | |
|---|---|---|---|---|---|---|---|
| | | M | F | M | F | M | F |
| **DERMAL** | 2-in-1 shampoo | 3.636E-07 | 2.178E-07 | 1.760E-07 | 1.038E-07 | 2.358E-07 | 1.417E-07 |
| | Body lotion | | | | | 3.625E-03 | 3.517E-03 |
| | Conditioner leave in | | | | | 2.498E-04 | 1.492E-04 |
| | Conditioner rinse off | | | | | 7.513E-06 | 4.497E-06 |
| | Soothing vapour | | | 1.447E-05 | 1.495E-05 | 6.662E-06 | 6.464E-06 |
| | Diaper cream | 5.665E-03 | 5.944E-03 | 2.742E-03 | 2.832E-03 | | |
| | Spray detangler | | | 1.654E-07 | 9.776E-08 | 7.617E-08 | 4.228E-08 |
| | Sunscreen | 2.409E-03 | 2.529E-03 | 2.915E-03 | 3.011E-03 | 2.684E-03 | 2.605E-03 |
| | ***Total Dermal*** | 8.075E-03 | 8.473E-03 | 5.672E-03 | 5.858E-03 | 6.573E-03 | 6.282E-03 |
| **INHALATION** | Indoor air | 2.403E-04 | 2.523E-04 | 2.251E-04 | 2.326E-04 | 1.515E-04 | 1.362E-04 |
| | Outdoor air | 4.775E-06 | 5.006E-06 | 4.472E-06 | 4.619E-06 | 3.012E-06 | 2.707E-06 |
| | Soothing vapor | | | 2.921E-03 | 3.017E-03 | 1.965E-03 | 1.767E-03 |
| | ***Total Inhalation*** | 2.451E-04 | 2.573E-04 | 3.151E-03 | 3.255E-03 | 2.119E-03 | 1.905E-03 |
| **INGESTION** | Antifoam | | | | | 9.252E-04 | 8.539E-04 |
| | Baby bottle nipple | | | | | | |
| | Fish, general | | | | | 4.499E-04 | 3.883E-04 |
| | Greens | | | | | 2.069E-08 | 2.126E-08 |
| | Human milk | | | | | | |
| | Meat | | | | | 7.121E-08 | 6.347E-08 |
| | Milk | | | | | 1.027E-07 | 8.833E-08 |
| | Pacifier | | | | | | |
| | Root vegetable | | | | | 1.129E-05 | 1.051E-05 |
| | Sipper tube | | | | | 5.176E-05 | 5.176E-05 |
| | Soil | | | | | 2.181E-06 | 2.116E-06 |
| | Straws | | | | | 2.133E-05 | 2.069E-05 |
| | Fish, subsistence | | | | | 3.770E-04 | 3.657E-04 |
| | Water | | | | | 1.461E-07 | 1.418E-07 |
| | OTC drugs | 5.434E-03 | 5.701E-03 | 1.316E-03 | 1.359E-03 | 2.213E-06 | 2.146E-06 |
| | ***Total Ingestion, Subsistence*** | 4.372E-03 | 4.372E-03 | 2.794E-03 | 2.794E-03 | 1.389E-03 | 1.305E-03 |
| | ***Total Ingestion, General*** | 2.654E-03 | 2.654E-03 | 2.428E-03 | 2.428E-03 | 1.462E-03 | 1.328E-03 |
| **TOTAL** | ***Total, Subsistence Population*** | 1.813E-02 | 1.880E-02 | 1.293E-02 | 1.327E-02 | 1.008E-02 | 9.494E-03 |
| | ***Total, General Population*** | 1.641E-02 | 1.709E-02 | 1.257E-02 | 1.290E-02 | 1.016E-02 | 9.517E-03 |

Table 1 summarizes all the exposure results for children as mean values. When compared with similar results generated by the SEHSC assessment, all the values are higher in the current assessment. Compared to the SEHSC assessment, the current assessment results in a difference of 1.79 to 2.32 times for total dermal exposures, in a difference of 1.00 to 13.56 times for total inhalation exposures, and in a difference of 0.97 to 1.56 times for total ingestion (general population) exposures. The primary reason for the differences is that the SEHSC assessed users and non-users whereas the current assessment considered users only.

Wherever exposures are estimated for multiple age groups, the estimates for lower age groups are usually greater than the estimates for higher age groups. Within dermal exposure scenarios, diaper cream, sunscreen and body lotion are the highest contributions; within inhalation, soothing vapour is the highest contributor; and within ingestion, the highest contributor is over-the-counter drugs for lower age groups and fish (subsistence) for higher age groups.

**Table 2. Mean ingestion exposures for breastfed (BF) and non-breastfed (nBF) infants**

| Mean exposures | | Ages 0–6 months | | 7–11 months | | 1–2 years | | 2–4 years |
|---|---|---|---|---|---|---|---|---|
| | | BF | nBF | BF | nBF | BF | nBF | all |
| **INGESTION** | Antifoam | 1.060E-03 | 2.904E-03 | 1.145E-03 | 2.260E-03 | 1.259E-03 | 1.821E-03 | 1.390E-03 |
| | Baby bottle nipple | | 4.871E-04 | | 3.484E-04 | | 2.900E-04 | 2.092E-04 |
| | Fish, general | 3.341E-06 | 3.980E-04 | 1.700E-04 | 4.794E-04 | 4.800E-04 | 4.828E-04 | 5.023E-04 |
| | Greens | 4.889E-08 | 3.968E-08 | 1.749E-08 | 3.329E-08 | 6.773E-08 | 2.030E-08 | 2.718E-08 |
| | Human milk | 3.425E-04 | | 2.009E-04 | | 1.124E-04 | | |
| | Meat | 5.972E-08 | 4.442E-08 | 5.182E-08 | 7.268E-08 | 5.008E-08 | 9.237E-08 | 9.152E-08 |
| | Milk | 1.355E-07 | 1.343E-07 | 6.381E-08 | 1.957E-07 | 1.778E-07 | 2.985E-07 | 1.639E-07 |
| | Pacifier | 4.873E-04 | 4.873E-04 | 3.485E-04 | 3.485E-04 | 2.902E-04 | 2.902E-04 | 2.093E-04 |
| | Root vegetable | 1.961E-05 | 2.103E-05 | 2.126E-05 | 2.799E-05 | 1.702E-05 | 1.998E-05 | 1.571E-05 |
| | Sipper tube | 2.436E-04 | 2.436E-04 | 1.743E-04 | 1.743E-04 | 1.451E-04 | 1.451E-04 | 1.046E-04 |
| | Soil | 9.959E-06 | 9.959E-06 | 7.123E-06 | 7.123E-06 | 5.929E-06 | 5.929E-06 | 4.277E-06 |
| | Straws | 4.873E-04 | 9.740E-05 | 6.967E-05 | 6.967E-05 | 5.799E-05 | 5.799E-05 | 4.184E-05 |
| | Fish, subsistence | 1.721E-03 | 1.721E-03 | 1.231E-03 | 1.231E-03 | 1.025E-03 | 1.025E-03 | 7.393E-04 |
| | Water | 6.673E-07 | 6.673E-07 | 4.773E-07 | 4.773E-07 | 3.973E-07 | 3.973E-07 | 2.866E-07 |

Table 2 summarizes all ingestion-related mean exposures specific to breastfed and non-breastfed infants. There are no significant differences in the results generated by the current assessment (shown above) and the SEHSC assessment. The two highest contributors to ingestion exposure for this subpopulation are antifoam and fish (subsistence).

**Table 3. Children's 90th percentile exposures (based on 200 000 Crystal Ball simulations)**

| 90th percentile exposures | | Ages 0–6 months | | 6 m – 4 yrs | | 4 yrs – 11 yrs | |
|---|---|---|---|---|---|---|---|
| | | M | F | M | F | M | F |
| **DERMAL** | 2–in-1 shampoo | 7.952E-07 | 4.747E-07 | 3.847E-07 | 2.260E-07 | 5.177E-07 | 3.132E-07 |
| | Body lotion | | | | | 7.894E-03 | 7.662E-03 |
| | Conditioner leave in | | | | | 5.265E-04 | 3.203E-04 |
| | Conditioner rinse off | | | | | 1.608E-05 | 9.733E-06 |
| | Soothing vapour | | | 2.019E-05 | 2.085E-05 | 9.294E-06 | 9.019E-06 |
| | Diaper cream | 1.463E-02 | 1.535E-02 | 7.073E-03 | 7.312E-03 | | |
| | Spray detangler | | | 3.192E-07 | 1.882E-07 | 1.468E-07 | 8.138E-08 |
| | Sunscreen | 7.264E-03 | 7.613E-03 | 8.766E-03 | 9.062E-03 | 8.081E-03 | 7.860E-03 |
| | ***Total Dermal*** | 1.849E-02 | 1.942E-02 | 1.244E-02 | 1.286E-02 | 1.391E-02 | 1.338E-02 |
| **INHALATION** | Indoor air | 5.001E-04 | 5.262E-04 | 4.700E-04 | 4.859E-04 | 3.185E-04 | 2.853E-04 |
| | Outdoor air | 1.137E-05 | 1.200E-05 | 1.071E-05 | 1.100E-05 | 7.186E-06 | 6.495E-06 |
| | Soothing vapour | | | 4.379E-03 | 4.522E-03 | 2.964E-03 | 2.640E-03 |
| | ***Total Inhalation*** | 5.038E-04 | 5.298E-04 | 4.663E-03 | 4.813E-03 | 3.155E-03 | 2.808E-03 |
| **INGESTION** | Antifoam | | | | | 1.680E-03 | 1.567E-03 |
| | Baby bottle nipple | | | | | | |
| | Fish, general | | | | | 1.008E-03 | 8.716E-04 |
| | Greens | | | | | 3.873E-09 | 4.007E-09 |
| | Human milk | | | | | | |
| | Meat | | | | | 1.425E-07 | 1.276E-07 |
| | Milk | | | | | 1.991E-07 | 1.747E-07 |
| | Pacifier | | | | | | |
| | Root vegetable | | | | | 2.966E-05 | 2.903E-05 |
| | Sipper tube | | | | | 6.587E-05 | 6.587E-05 |
| | Soil | | | | | 4.180E-06 | 4.056E-06 |
| | Straws | | | | | 2.715E-05 | 2.634E-05 |
| | Fish, subsistence | | | | | 8.404E-04 | 8.146E-04 |
| | Water | | | | | 2.901E-07 | 2.813E-07 |
| | OTC drugs | 1.304E-02 | 1.366E-02 | 3.627E-03 | 3.746E-03 | 5.306E-06 | 5.150E-06 |
| | ***Total Ingestion, Subsistence*** | 7.195E-03 | 7.195E-03 | 4.406E-03 | 4.406E-03 | 2.333E-03 | 2.203E-03 |
| | ***Total Ingestion, General*** | 4.326E-03 | 4.326E-03 | 3.804E-03 | 3.804E-03 | 2.488E-03 | 2.266E-03 |
| **TOTAL** | ***Total, Subsistence Population*** | 3.317E-02 | 3.456E-02 | 2.201E-02 | 2.260E-02 | 1.756E-02 | 1.673E-02 |
| | ***Total, General Population*** | 3.102E-02 | 3.242E-02 | 2.155E-02 | 2.215E-02 | 1.773E-02 | 1.677E-02 |

Table 3 summarizes all the exposure results for children as 90th percentile values. When compared with similar results generated by the SEHSC assessment, all the values are higher in the current assessment. Compared to the SEHSC assessment, the current assessment results in a difference of 1.33 to 1.69 times for total dermal exposures, in a difference of 1.00 to 9.83 times for total inhalation exposures, and in a difference of 0.97 to 1.36 times for total ingestion (general population) exposures. The primary reason for the differences is that the SEHSC assessed users and non-users whereas the current assessment considered users only.

**Table 4. 90th percentile ingestion exposures for breastfed (BF) and non-breastfed (nBF) infants**

| 90th percentile exposures | | Ages 0–6 months | | 7–11 months | | 1–2 years | | 2–4 years |
|---|---|---|---|---|---|---|---|---|
| | | BF | nBF | BF | nBF | BF | nBF | all |
| **INGESTION** | Antifoam | 2.706E-03 | 5.188E-03 | 2.490E-03 | 3.981E-03 | 2.423E-03 | 3.240E-03 | 2.487E-03 |
| | Baby bottle nipple | | 6.202E-04 | | 4.434E-04 | | 3.901E-04 | 2.663E-04 |
| | Fish, general | 6.719E-06 | 9.746E-04 | 3.701E-04 | 1.082E-03 | 1.146E-03 | 1.063E-03 | 1.126E-03 |
| | Greens | 1.028E-08 | 1.011E-08 | 2.465E-09 | 6.328E-09 | 1.852E-08 | 3.972E-09 | 4.953E-09 |
| | Human milk | 4.587E-04 | | 3.428E-04 | | 1.952E-04 | | |
| | Meat | 1.471E-07 | 9.750E-08 | 1.133E-07 | 1.476E-07 | 9.887E-08 | 1.841E-07 | 1.825E-07 |
| | Milk | 3.244E-07 | 3.045E-07 | 1.349E-07 | 4.601E-07 | 3.777E-07 | 5.904E-07 | 3.267E-07 |
| | Pacifier | 6.201E-04 | 6.201E-04 | 4.432E-04 | 4.432E-04 | 3.907E-04 | 3.907E-04 | 2.662E-04 |
| | Root vegetable | 5.571E-05 | 6.142E-05 | 5.768E-05 | 7.632E-05 | 4.353E-05 | 5.262E-05 | 4.168E-05 |
| | Sipper tube | 3.100E-04 | 3.100E-04 | 2.216E-04 | 2.216E-04 | 1.953E-04 | 1.953E-04 | 1.331E-04 |
| | Soil | 1.909E-05 | 1.909E-05 | 1.365E-05 | 1.365E-05 | 1.146E-05 | 1.146E-05 | 8.200E-06 |
| | Straws | 6.201E-04 | 1.240E-04 | 8.864E-05 | 8.864E-05 | 7.805E-05 | 7.805E-05 | 5.323E-05 |
| | Fish, subsistence | 3.837E-03 | 3.837E-03 | 2.744E-03 | 2.744E-03 | 2.284E-03 | 2.284E-03 | 1.648E-03 |
| | Water | 1.325E-06 | 1.325E-06 | 9.479E-07 | 9.479E-07 | 7.950E-07 | 7.950E-07 | 5.691E-07 |

Table 4 summarizes all ingestion-related 90th percentile exposures specific to breastfed and non-breastfed infants. There are no significant differences in the results generated by the current assessment (shown above) and the SEHSC assessment. The two highest contributors to ingestion exposure for this subpopulation are antifoam and fish (subsistence).

**Figure 1. Contribution of scenarios to children's mean and 90th percentile dermal exposures**

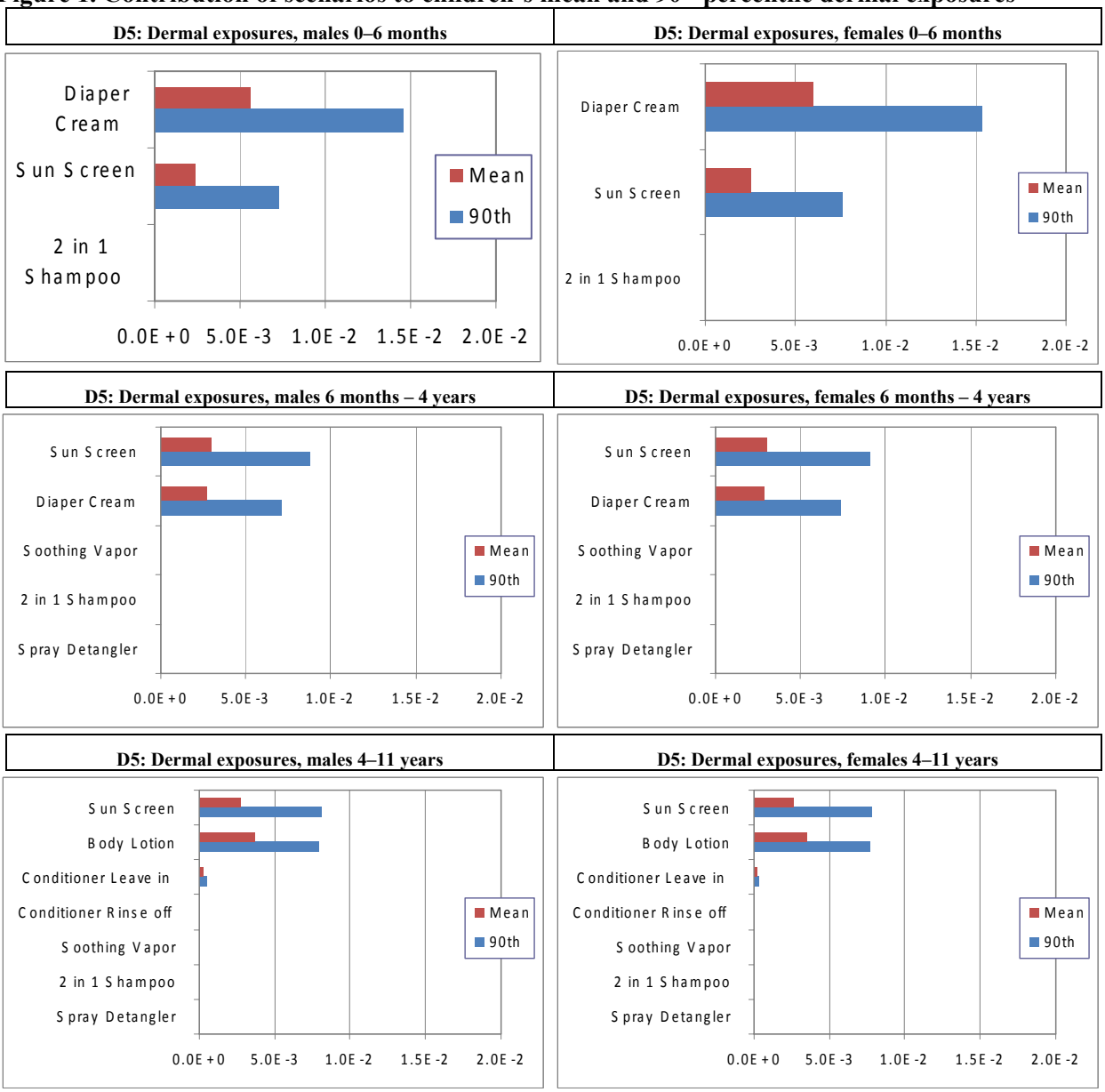


Figure 1 shows the contribution of scenarios to dermal exposures for children's mean and 90th percentile exposures. As seen in the bar charts, diaper cream, sunscreen, and body lotion are the highest contributors to dermal exposures.

**Figure 2. Contribution of scenarios to children's mean and 90th percentile inhalation exposures**

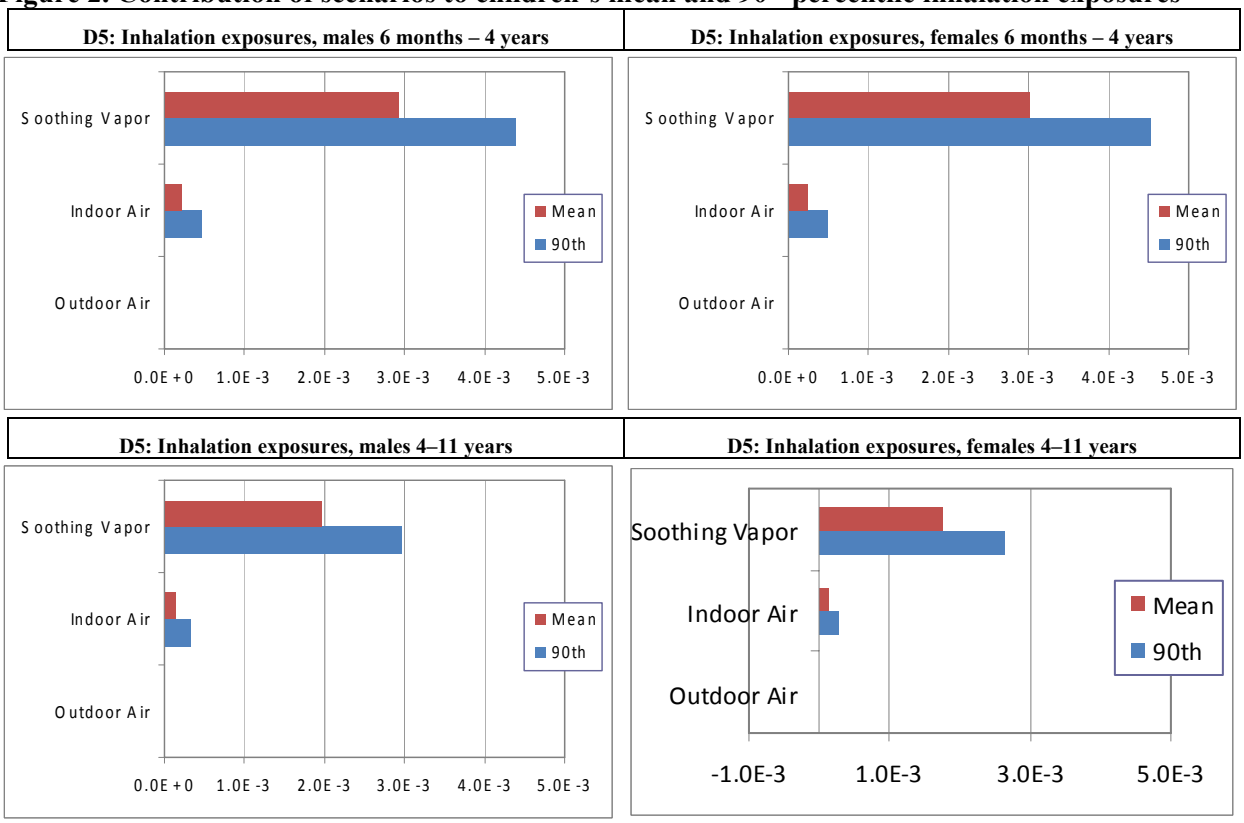


Figure 2 shows the contribution of scenarios to inhalation exposures for children's mean and 90th percentile exposures. As seen in the bar charts, soothing vapour is the highest contributor to inhalation exposures.

**Figure 3. Contribution of scenarios to children's (breastfed vs. non-breastfed) mean and 90th percentile ingestion exposures**

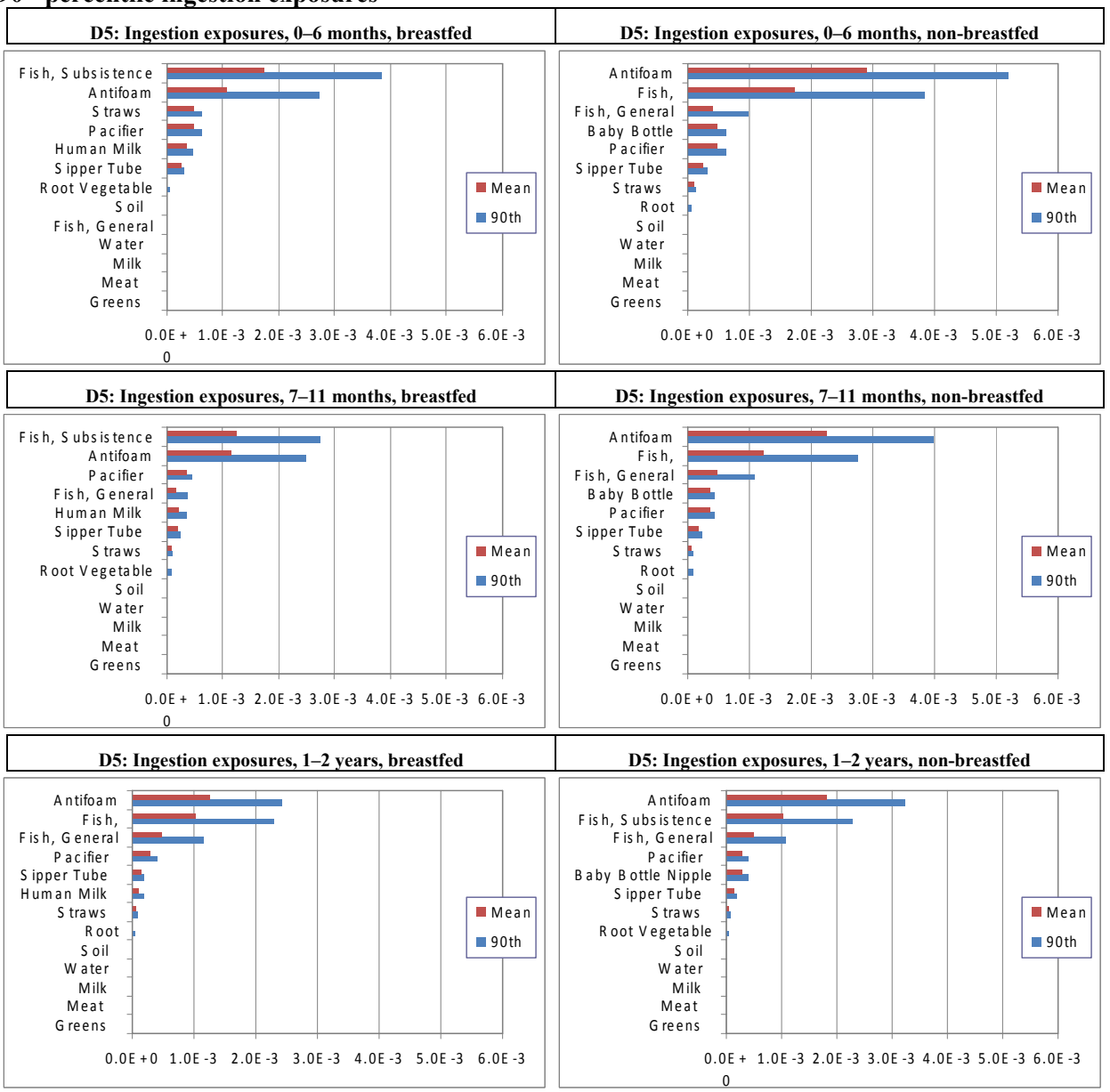


Figure 3 shows the contribution of scenarios to ingestion exposures for children's (breastfed and non-breastfed) mean and 90th percentile exposures. As seen in the bar charts, the highest contributors to ingestion exposures for this subpopulation are antifoam and fish (for the general and subsistence population).

**Figure 4. Contribution of scenarios to children's (2–4 and 4–11 years) mean and 90th percentile ingestion exposures**

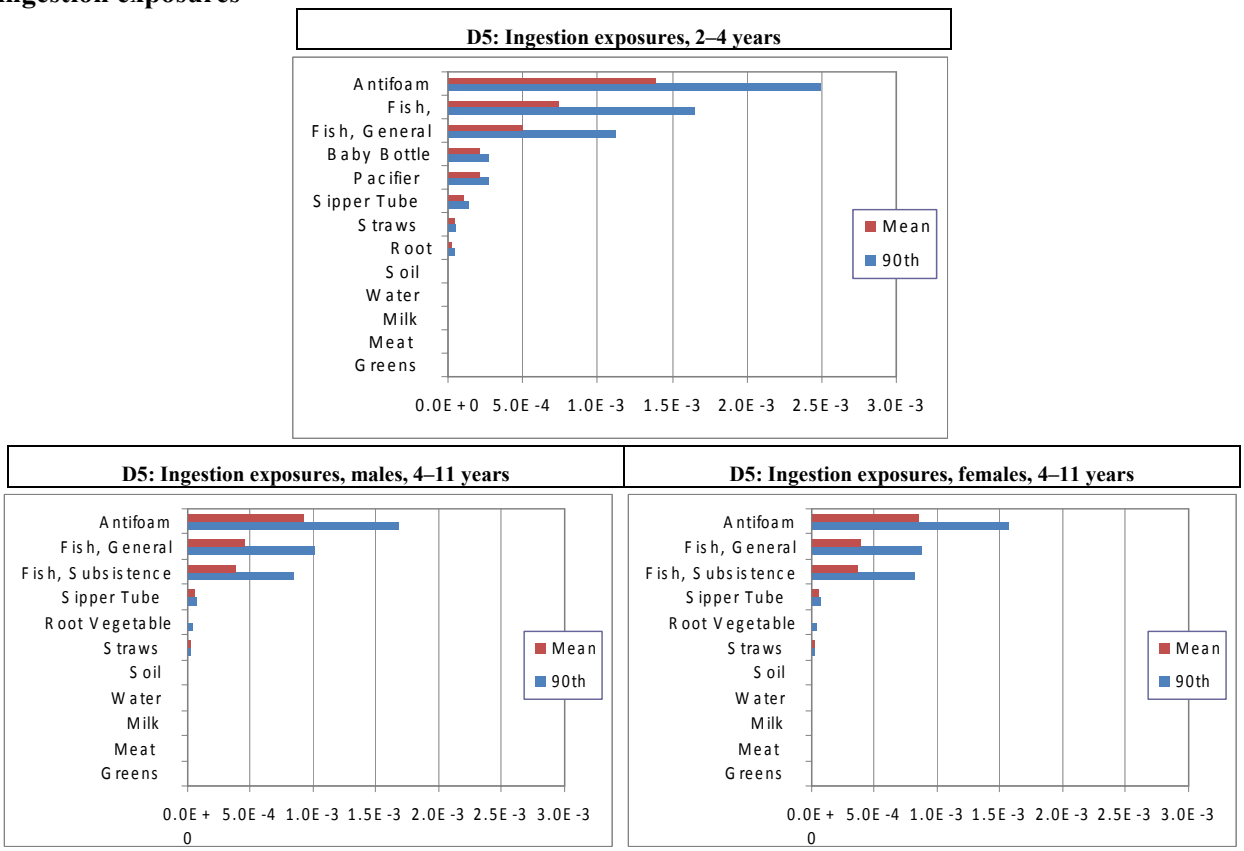


Figure 4 shows the contribution of scenarios to ingestion exposures for children's (2–4 and 4–11 years) mean and 90th percentile exposures. Exposure estimates are based on 200 000 Crystal Ball simulations. As seen in the bar charts, the highest contributors to ingestion exposures for this subpopulation are antifoam and fish (for general and subsistence population).

**Figure 5. Contribution of exposure route to children's mean and 90th percentile total exposure (general population)**

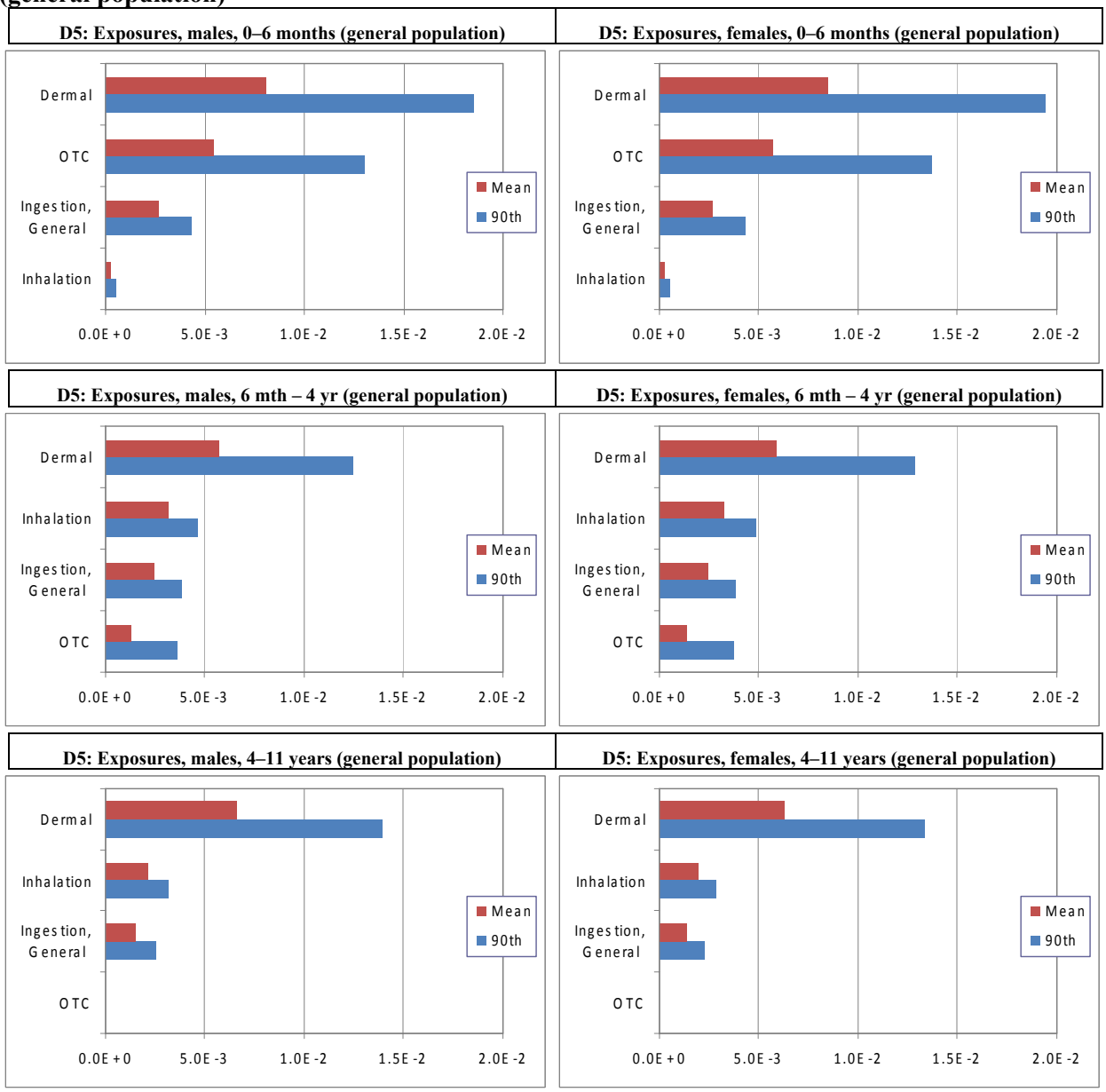


Figure 5 shows the contribution of exposure route to children's mean and 90th percentile total exposures for the general population. The highest exposure route is dermal. In the case of children0–6 months old, dermal exposure is followed by over-the-counter drugs and then by ingestion; however, in the case of children 6 months – 4 years old and children 4–11 years old, dermal exposure is followed by inhalation and then by ingestion.

**Figure 6. Contribution of exposure route to children's mean and 90th percentile total exposure (subsistence population)**

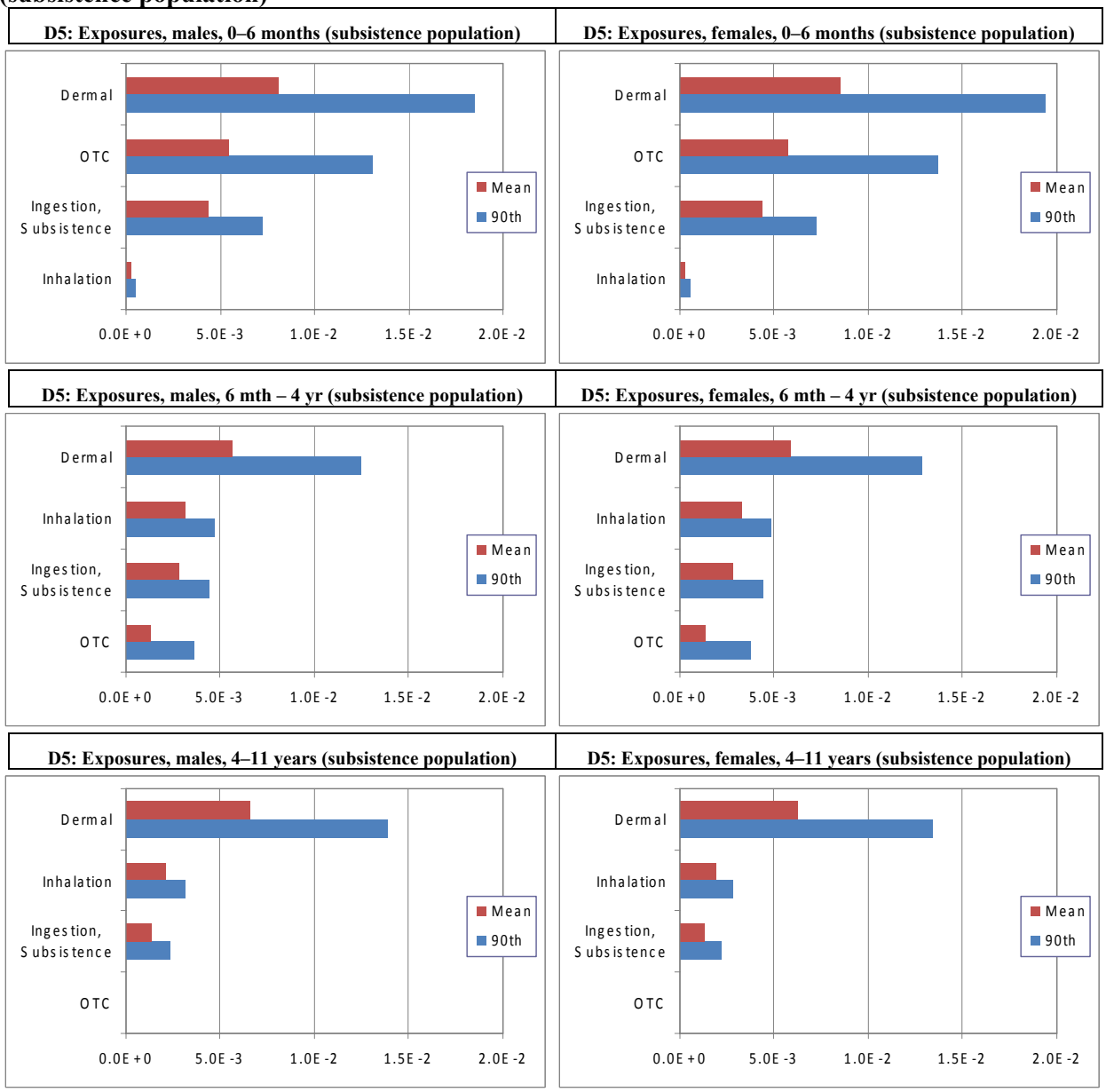


Figure 6 shows the contribution of exposure route to children's mean and 90th percentile total exposures for the subsistence population. The highest exposure route is dermal. In the case of children 0–6 months old, dermal exposure is followed by over-the-counter drugs and then by ingestion; however, in the case of children 6 months – 4 years old and children 4–11 years old, dermal exposure is followed by inhalation and then by ingestion.

## EXPOSURE RESULTS AND DISCUSSION: ADULTS

**Table 5. Adults' mean exposures (based on 200 000 Crystal Ball simulations)**

| Mean exposures | | 12–19 years | | 20–59 years | | 60+ years | |
|---|---|---|---|---|---|---|---|
| | | **Males** | **Females** | **Males** | **Females** | **Males** | **Females** |
| **DERMAL** | After shave | 1.07E-04 | | 8.25E-05 | | 8.45E-05 | |
| | Body lotion | 3.11E-03 | 3.46E-03 | 2.40E-03 | 2.83E-03 | 2.45E-03 | 2.93E-03 |
| | Soothing vapour | 3.07E-06 | 3.41E-06 | 2.37E-06 | 2.80E-06 | 2.42E-06 | 2.90E-06 |
| | Foundation | | 1.47E-04 | | 1.21E-04 | | 1.25E-04 |
| | Hair spray | 1.09E-04 | 6.44E-05 | 8.36E-05 | 5.28E-05 | 8.56E-05 | 5.46E-05 |
| | Leave-in condition | 6.21E-05 | 3.70E-05 | 4.78E-05 | 3.04E-05 | 4.89E-05 | 3.14E-05 |
| | Rinse-off conditioner | 1.86E-06 | 1.11E-06 | 1.43E-06 | 9.08E-07 | 1.47E-06 | 9.40E-07 |
| | Mascara | | 3.45E-05 | | 2.83E-05 | | 2.93E-05 |
| | Moisturizer | | 1.18E-03 | | 9.70E-04 | | 1.00E-03 |
| | Nail care | | 1.14E-04 | | 9.31E-05 | | 9.65E-05 |
| | Roll-on antiperspirant | 5.58E-04 | 4.13E-04 | 4.29E-04 | 3.38E-04 | 4.40E-04 | 3.51E-04 |
| | Shampoo | 1.17E-07 | 6.95E-08 | 9.04E-08 | 5.70E-08 | 9.26E-08 | 5.90E-08 |
| | Solid antiperspiramt | 6.54E-04 | 4.47E-04 | 5.03E-04 | 3.66E-04 | 5.15E-04 | 3.79E-04 |
| | Sunscreen | 1.88E-03 | 2.09E-03 | 1.45E-03 | 1.71E-03 | 1.48E-03 | 1.77E-03 |
| | Under-eye cream | | | | 4.24E-05 | | 4.39E-05 |
| | ***Total Dermal*** | 6.49E-03 | 7.99E-03 | 5.00E-03 | 6.59E-03 | 5.11E-03 | 6.83E-03 |
| **INHALATION** | Indoor air | 8.48E-05 | 6.94E-05 | 6.13E-05 | 5.28E-05 | 5.36E-05 | 4.91E-05 |
| | Outdoor air | 1.69E-06 | 1.38E-06 | 1.22E-06 | 1.05E-06 | 1.07E-06 | 9.77E-07 |
| | Soothing vapour | 1.10E-03 | 9.01E-04 | 7.96E-04 | 6.86E-04 | 6.95E-04 | 6.37E-04 |
| | ***Total inhalation*** | 1.19E-03 | 9.72E-04 | 8.59E-04 | 7.40E-04 | 7.50E-04 | 6.87E-04 |
| **INGESTION** | Fish, general population | 3.08E-04 | 2.24E-04 | 2.39E-04 | 2.36E-04 | 2.35E-04 | 2.68E-04 |
| | Leafy vegetables | 1.90E-08 | 1.75E-08 | 2.21E-08 | 2.51E-08 | 2.45E-08 | 2.71E-08 |
| | Root crops | 8.39E-06 | 6.83E-06 | 7.49E-06 | 6.30E-06 | 7.33E-06 | 6.59E-06 |
| | Lipstick | | 1.26E-05 | | 1.03E-05 | | 1.07E-05 |
| | Meat | 5.47E-08 | 3.76E-08 | 4.68E-08 | 3.32E-08 | 3.28E-08 | 2.86E-08 |
| | Milk | 4.63E-08 | 3.20E-08 | 1.97E-08 | 1.89E-08 | 2.05E-08 | 1.97E-08 |
| | Soil | 5.90E-07 | 6.55E-07 | 4.54E-07 | 5.37E-07 | 4.65E-07 | 5.56E-07 |
| | Fish, subsistence population | 4.07E-04 | 4.51E-04 | 3.13E-04 | 3.70E-04 | 3.20E-04 | 3.83E-04 |
| | Water | 1.01E-07 | 1.13E-07 | 1.02E-07 | 1.20E-07 | 1.04E-07 | 1.24E-07 |
| | Antifoam | 8.09E-04 | 7.98E-04 | 7.07E-04 | 6.38E-04 | 5.89E-04 | 5.63E-04 |
| | OTC drugs | 1.02E-06 | 1.13E-06 | 7.84E-07 | 9.26E-07 | 8.02E-07 | 9.59E-07 |
| | ***Total Ingestion, General*** | 1.13E-03 | 1.04E-03 | 9.55E-04 | 8.92E-04 | 8.32E-04 | 8.49E-04 |
| | ***Total Ingestion, Subsistence*** | 1.23E-03 | 1.27E-03 | 1.03E-03 | 1.03E-03 | 9.17E-04 | 9.65E-04 |
| **TOTAL** | ***General Population*** | 8.80E-03 | 1.00E-02 | 6.81E-03 | 8.22E-03 | 6.70E-03 | 8.36E-03 |
| | ***Subsistence Population*** | 8.90E-03 | 1.02E-02 | 6.88E-03 | 8.36E-03 | 6.78E-03 | 8.48E-03 |

Table 5 summarizes all the exposure results for adults as mean values. When compared with similar results generated by the SEHSC assessment, almost all the values are higher in the current assessment. Compared to the SEHSC assessment, the current assessment results in a difference of about 2.16 times for total dermal exposures, in a difference of about 13.55 times for total inhalation exposures, and in a difference of about 1.24 times for total ingestion (general population) exposures. The primary reason for the differences is that the SEHSC assessed users and non-users whereas the current assessment considered users only.

**Table 6. Adults' 90th percentile exposures (based on 200 000 Crystal Ball simulations)**

| 90th percentile exposures | | 12–19 years | | 20–59 years | | 60+ years | |
|---|---|---|---|---|---|---|---|
| | | **Males** | **Females** | **Males** | **Females** | **Males** | **Females** |
| **DERMAL** | After shave | 1.62E-04 | | 1.24E-04 | | 1.27E-04 | |
| | Body lotion | 6.77E-03 | 7.51E-03 | 5.21E-03 | 6.16E-03 | 5.33E-03 | 6.38E-03 |
| | Soothing vapour rub | 4.29E-06 | 4.76E-06 | 3.30E-06 | 3.90E-06 | 3.38E-06 | 4.04E-06 |
| | Foundation | | 3.69E-04 | | 3.02E-04 | | 3.13E-04 |
| | Hair spray | 2.70E-04 | 1.54E-04 | 2.08E-04 | 1.26E-04 | 2.13E-04 | 1.31E-04 |
| | Leave-in condition | 1.92E-04 | 1.07E-04 | 1.48E-04 | 8.79E-05 | 1.51E-04 | 9.10E-05 |
| | Rinse-off conditioner | 5.74E-06 | 3.18E-06 | 4.42E-06 | 2.61E-06 | 4.52E-06 | 2.70E-06 |
| | Mascara | | 6.19E-05 | | 5.08E-05 | | 5.26E-05 |
| | Moisturizer | | 2.79E-03 | | 2.29E-03 | | 2.37E-03 |
| | Nail care | | 1.16E-04 | | 9.44E-05 | | 9.75E-05 |
| | Roll-on antiperspirant | 1.07E-03 | 7.92E-04 | 8.26E-04 | 6.48E-04 | 8.45E-04 | 6.72E-04 |
| | Shampoo | 2.50E-07 | 1.59E-07 | 1.92E-07 | 1.30E-07 | 1.97E-07 | 1.35E-07 |
| | Solid antiperspirant | 8.73E-04 | 9.63E-04 | 6.72E-04 | 7.90E-04 | 6.87E-04 | 8.18E-04 |
| | Sunscreen | 3.38E-03 | 3.75E-03 | 2.60E-03 | 3.07E-03 | 2.66E-03 | 3.18E-03 |
| | Under-eye cream | | | | 7.33E-05 | | 7.59E-05 |
| | ***Total Dermal*** | 1.04E-02 | 1.29E-02 | 8.01E-03 | 1.06E-02 | 8.20E-03 | 1.10E-02 |
| **INHALATION** | Indoor air | 1.76E-04 | 1.43E-04 | 1.27E-04 | 1.09E-04 | 1.11E-04 | 1.01E-04 |
| | Outdoor air | 4.02E-06 | 3.31E-06 | 2.93E-06 | 2.52E-06 | 2.56E-06 | 2.33E-06 |
| | Soothing vapour | 1.62E-03 | 1.29E-03 | 1.13E-03 | 9.69E-04 | 9.93E-04 | 9.03E-04 |
| | ***Total inhalation*** | 1.72E-03 | 1.37E-03 | 1.20E-03 | 1.03E-03 | 1.05E-03 | 9.58E-04 |
| **INGESTION** | Fish, general population | 6.91E-04 | 5.20E-04 | 5.39E-04 | 5.25E-04 | 5.20E-04 | 5.92E-04 |
| | Leafy vegetables | 3.75E-09 | 3.39E-09 | 4.00E-09 | 4.47E-09 | 4.60E-09 | 4.78E-09 |
| | Root crops | 2.24E-05 | 1.81E-05 | 2.04E-05 | 1.75E-05 | 2.03E-05 | 1.85E-05 |
| | Lipstick | | 3.13E-05 | | 2.57E-05 | | 2.66E-05 |
| | Meat | 1.08E-07 | 7.57E-08 | 9.41E-08 | 6.64E-08 | 6.51E-08 | 5.70E-08 |
| | Milk | 9.47E-08 | 6.81E-08 | 4.11E-08 | 4.00E-08 | 4.14E-08 | 4.14E-08 |
| | Soil | 7.96E-07 | 8.83E-07 | 6.12E-07 | 7.23E-07 | 6.27E-07 | 7.49E-07 |
| | Fish, subsistence population | 9.09E-04 | 1.01E-03 | 6.99E-04 | 8.27E-04 | 7.17E-04 | 8.56E-04 |
| | Water | 1.91E-07 | 2.12E-07 | 1.74E-07 | 2.06E-07 | 1.78E-07 | 2.13E-07 |
| | Antifoam | 1.46E-03 | 1.24E-03 | 1.26E-03 | 1.15E-03 | 1.03E-03 | 1.00E-03 |
| | OTC drugs | 2.45E-06 | 2.72E-06 | 1.88E-06 | 2.23E-06 | 1.93E-06 | 2.31E-06 |
| | ***Total Ingestion, General*** | 1.94E-03 | 1.56E-03 | 1.65E-03 | 1.54E-03 | 1.40E-03 | 1.44E-03 |
| | ***Total Ingestion, Subsistence*** | 2.09E-03 | 1.95E-03 | 1.76E-03 | 1.76E-03 | 1.54E-03 | 1.64E-03 |
| **TOTAL** | ***General Population*** | 1.28E-02 | 1.50E-02 | 9.95E-03 | 1.23E-02 | 9.87E-03 | 1.26E-02 |
| | ***Subsistence Population*** | 1.30E-02 | 1.52E-02 | 1.00E-02 | 1.25E-02 | 9.96E-03 | 1.27E-02 |

Table 6 summarizes all the exposure results for adults as 90th percentile values. When compared with similar results generated by the SEHSC assessment, almost all the values are higher in the current assessment. Compared to the SEHSC assessment, the current assessment results in a difference of about 1.55 times for total dermal exposures, in a difference of about 9.44 times for total inhalation exposures, and in a difference of about 1.17 times for total ingestion (general population) exposures. The primary reason for the differences is that the SEHSC assessed users and non-users whereas the current assessment considered users only.

**Figure 7. Contribution of scenarios to adults' mean and 90th percentile dermal exposures**

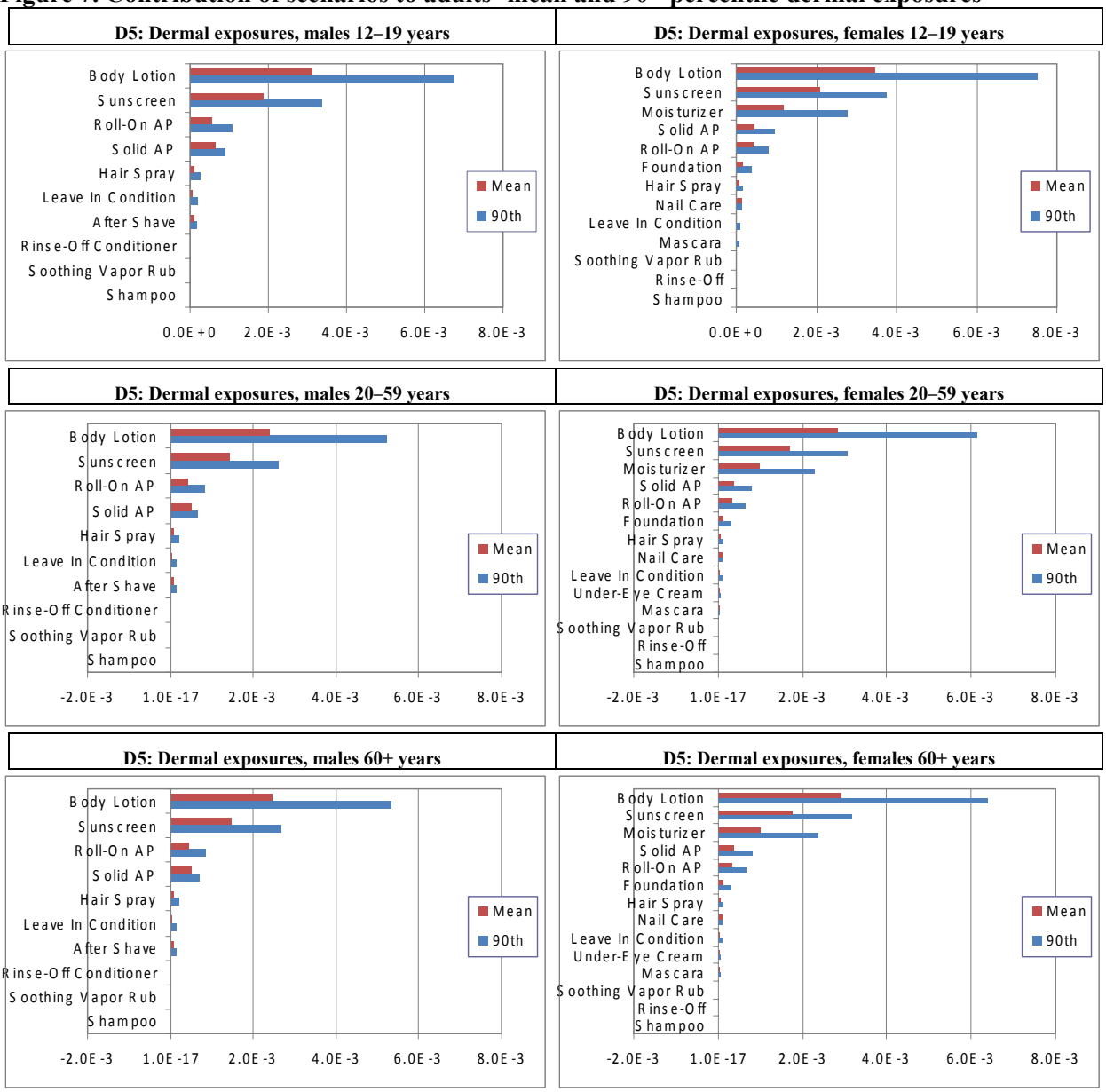


Figure 7 (above) shows the contribution of scenarios to dermal exposures for adults' mean and 90th percentile exposures. As seen in the bar charts, body lotion, sunscreen, and moisturizer are the highest contributors to dermal exposures.

**Figure 8. Contribution of scenarios to adults' mean and 90th percentile inhalation exposures**

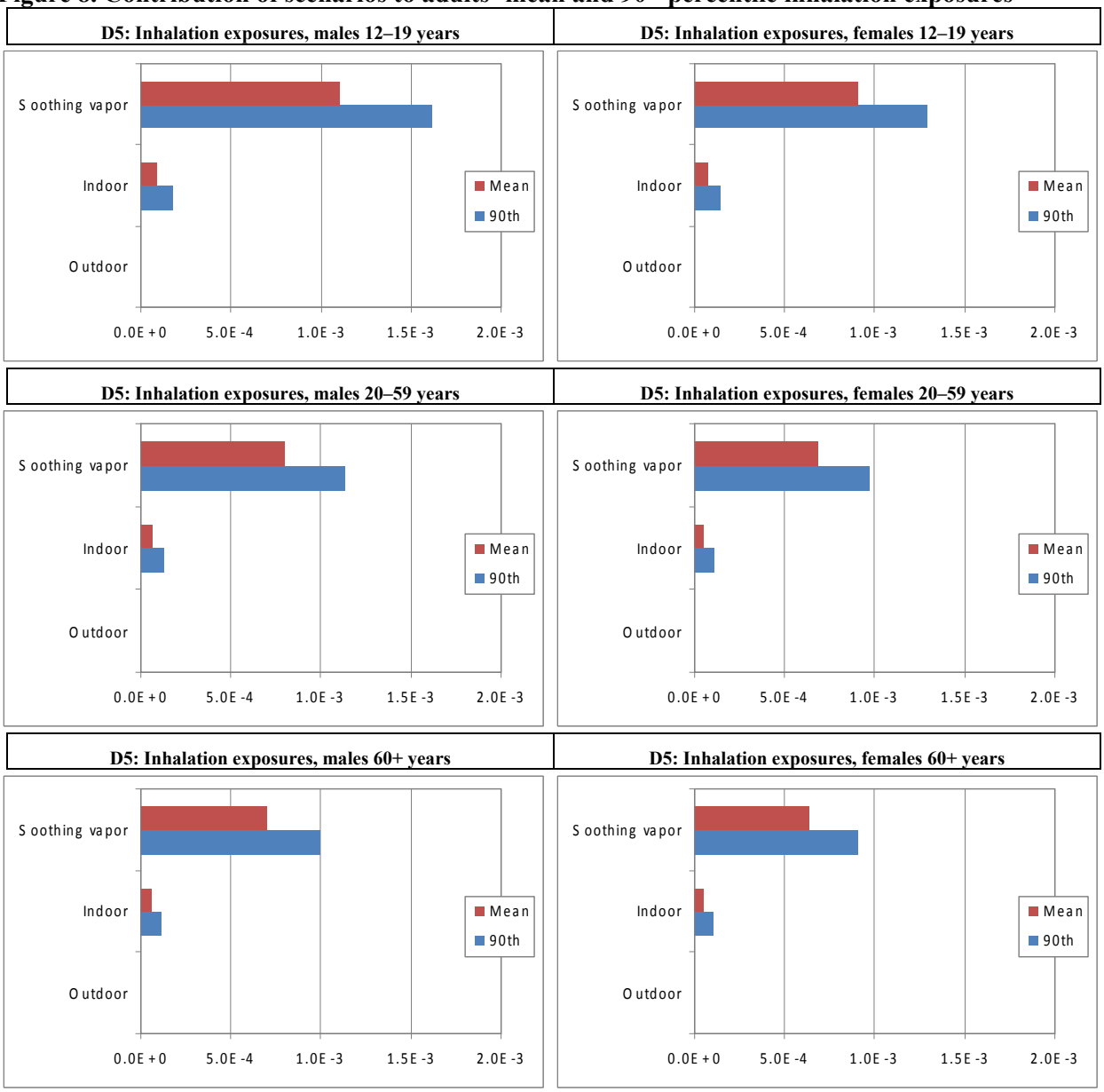


Figure 8 shows the contribution of scenarios to inhalation exposures for adults' mean and 90th percentile exposures. As seen in the bar charts, soothing vapour is the highest contributor to inhalation exposures.

**Figure 9. Contribution of scenarios to adults' mean and 90th percentile ingestion exposures**

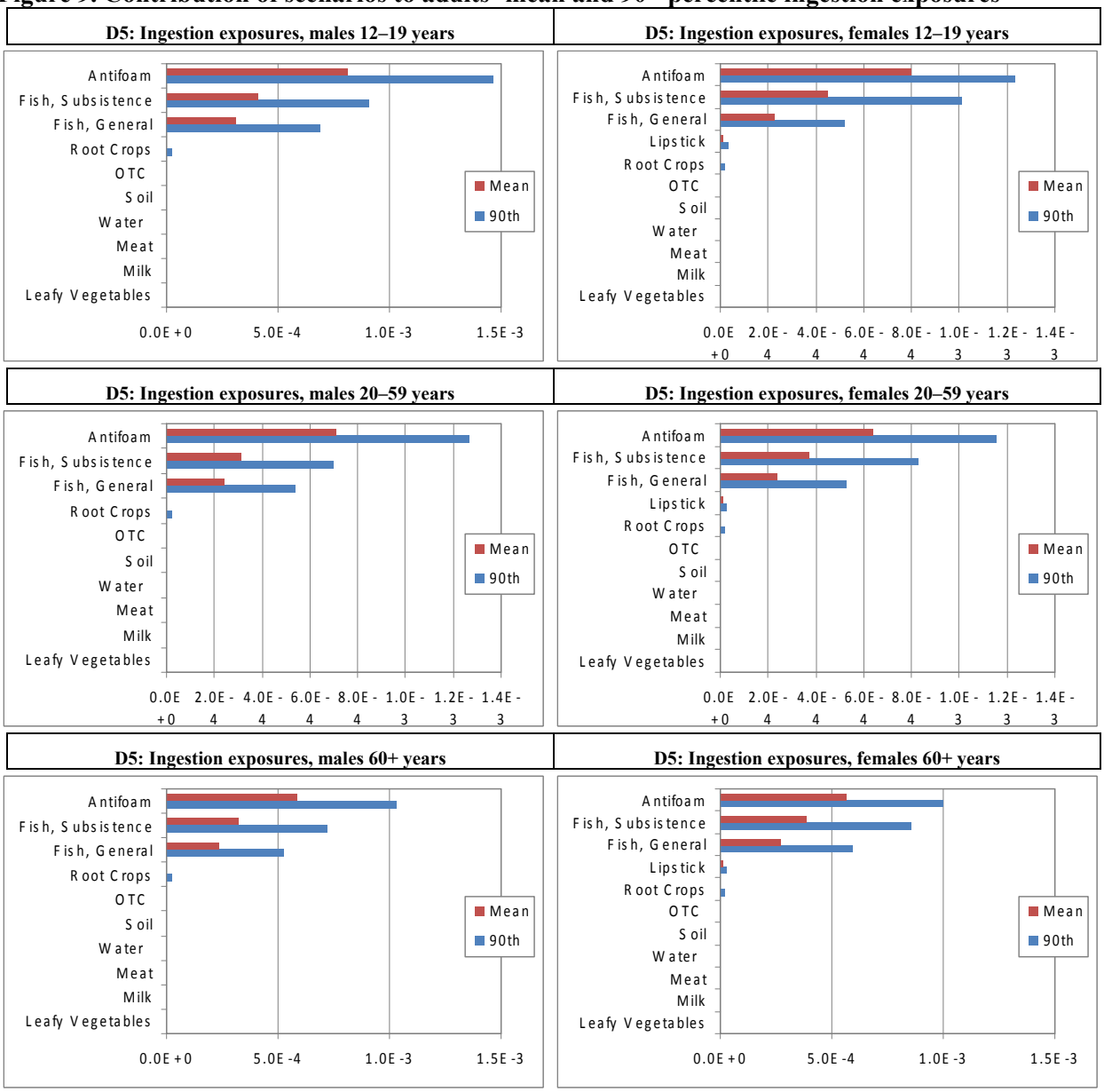


Figure 9 shows the contribution of scenarios to ingestion exposures (general population) for adults' mean and 90th percentile exposures. As seen in the bar charts, antifoam and fish are the highest contributors to ingestion exposures.

**Figure 10. Contribution of exposure route to adults' mean and 90th percentile total exposure (general population)**

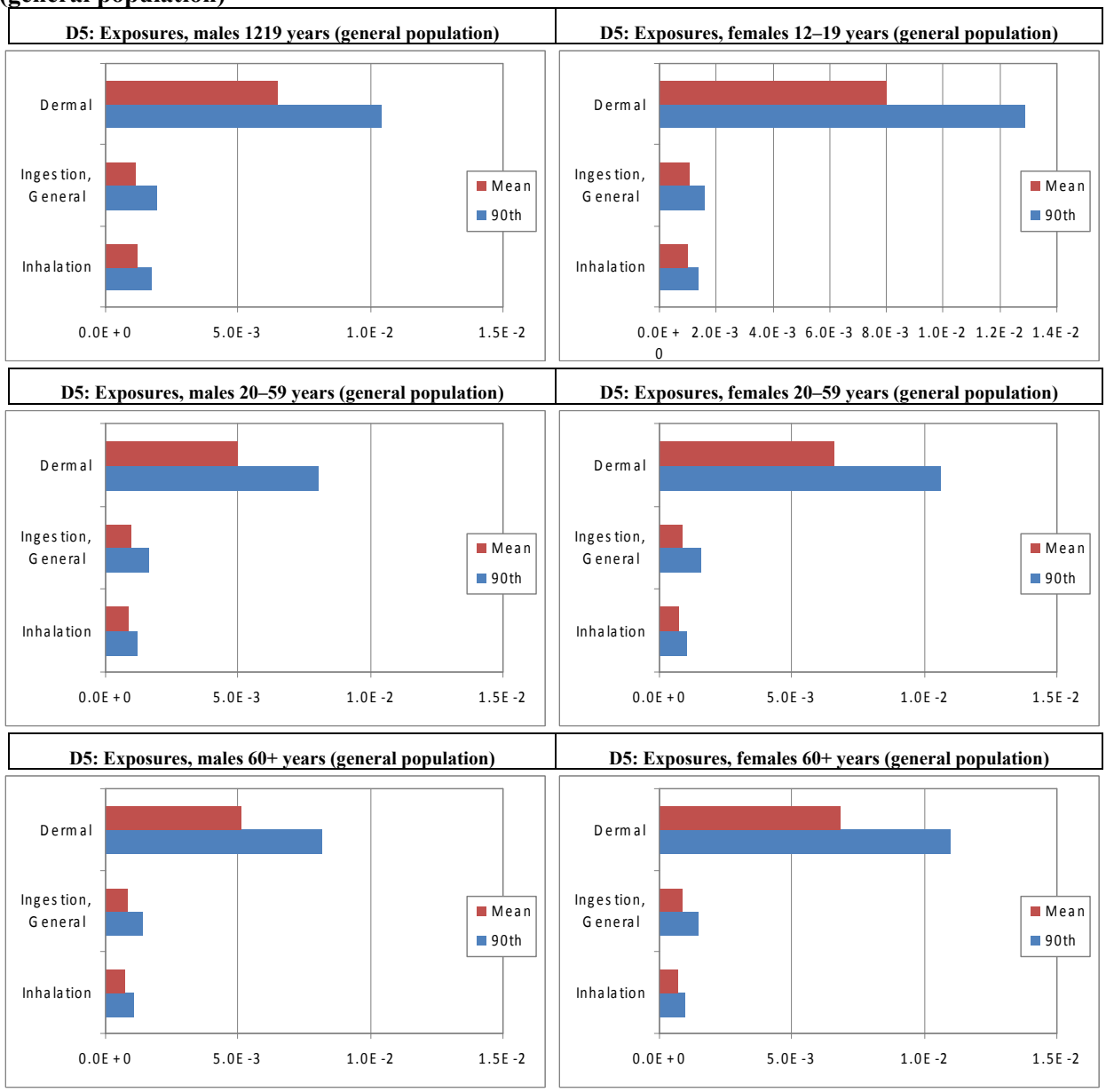


Figure 10 shows the contribution of exposure route to adults' mean and 90th percentile total exposures for the general population. The highest exposure route is dermal. Dermal is followed by ingestion and inhalation.

**Figure 11. Contribution of exposure route to adults' mean and 90th percentile total exposure (subsistence population)**

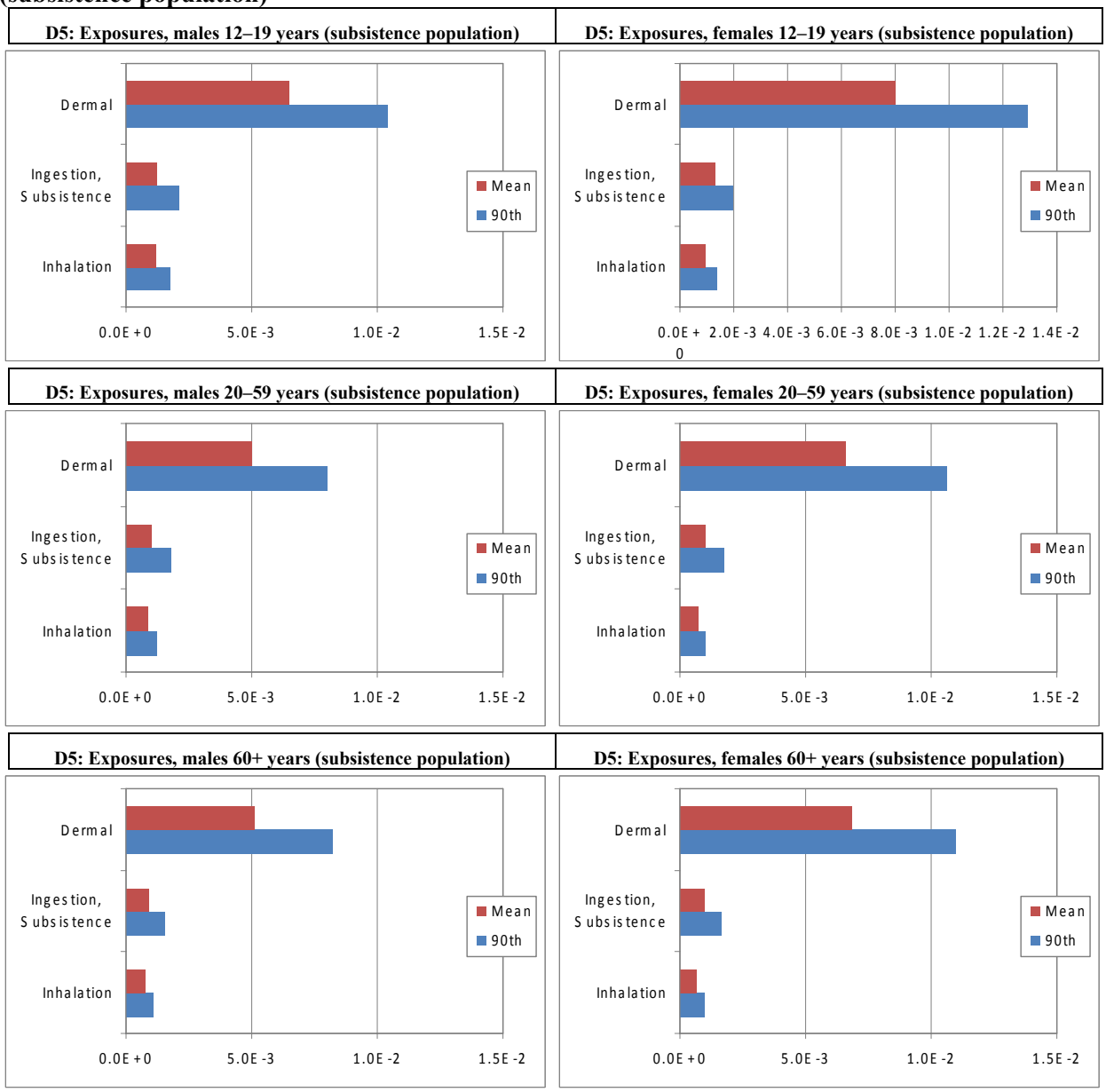


Figure 11 shows the contribution of exposure route to adults' mean and 90th percentile total exposures for the subsistence population. The highest exposure route is dermal. Dermal is followed by ingestion and inhalation.

## Appendix 5: Multimedia modelling input parameters for D4 in the ecological screening assessment

| Model input parameter | Value |
|---|---|
| **Molecular weight (g/mol)** | 297 |
| **Melting point (ºC)** | 17.5 |
| **Boiling point (ºC)** | 175.8 |
| **Data temperature (ºC)** | 25 |
| **Density (kg/m$^3$)** | 950 |
| **Vapour pressure (Pa)** | 140 (1.05 mm Hg) |
| **Henry's Law constant (Pa·m$^3$/mol)** | 1 220 000 (12.0 atm·m$^3$/mol) |
| **Log $K_{aw}$ (Air-water partition coefficient; dimensionless)** | 2.69 |
| **Log $K_{ow}$ (Octanol-water partition coefficient; dimensionless)** | 6.49 |
| **Log $K_{oc}$ (Organic carbon-water partition coefficient – L/kg)** | 4.22 |
| **Water solubility (mg/L)** | 0.056 |
| **Log $K_{oa}$ (Octanol-air partition coefficient; dimensionless)** | 4.34 |
| **Soil-water partition coefficient (L/kg)** | 332 |
| **Sediment-water partition coefficient (L/kg)** | 664 |
| **Suspended particles-water partition coefficient (L/kg)** | 3320 |
| **Fish-water partition coefficient (L/kg)** | 13 400 |
| **Aerosol-water partition coefficient; dimensionless** | 100 |
| **Vegetation-water partition coefficient; dimensionless** | 166 |
| **Half-life in air (days)** | 10.6 |
| **Half-life in water (days)** | 3.7 |
| **Half-life in sediment (days)** | 49 |
| **Half-life in soil (days)** | 5.25 |
| **Half-life in vegetation (days)** | 3.7 |