Review II:
Perfluorooctanoic Acid (PFOA) In The Environment

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Report Number:
DuPont-19567

May 23, 2006

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Table of Contents

Executive Summary

This review of PFOA in the environment is based on findings from a literature search on perfluorooctanoic acid ($C_8F_{15}O_2H$), perfluorooctanoate anion ($C_8F_{15}O_2$), and ammonium perfluorooctanoate (NH_4^+, $C_8F_{15}O_2^-$). This review is limited to PFOA found in the environment and does not include any evaluation of potential PFOA precursors nor potential PFOA sources. The sources for review included public records, company records, journals, books, and meeting abstracts (e.g., SETAC, FLUOROS, and DIOXIN meetings).

Considering international criteria (see page ix, Table 1) for persistence (P), PFOA meets the criteria for persistence based on expected half-lives of PFOA via biodegradation, hydrolysis, and photolysis under environmentally relevant conditions. It is anticipated that PFOA will exist predominantly in the water compartment. Partitioning to sludges, soils, and sediments will likely be very limited and any PFOA associated with these environmental matrices will likely be found in the water phase of sludges, soils, and sediments. However, there are still significant uncertainties concerning the environmental fate of PFOA including: 1) sources of PFOA in the environment; 2) potential for biotransformation in soil and sediments under varying environmental conditions and anaerobic sludges; 3) transport / distribution mechanisms; and 4) ultimate sinks.

All available evidence indicates that PFOA is not bioaccumulative (i.e., B) considering the international criteria (see page ix, Table 1) for bioaccumulation. PFOA is not bioaccumulative based on both the reported bioaccumulation factor (BAF) and bioconcentration factor (BCF) values and it does not biomagnify in the food chain.

Several groups of organisms and species were tested to assess the acute and chronic toxicity of PFOA including a soil nematode (*Caenorhabditis elegans*), and various aquatic organisms including a mixed bacterial community found in sewage sludge, the marine bacterium, *Photobacterium phosphoreum* (i.e., Microtox), the fathead minnow *(Pimephales promelas),* bluegill sunfish *(Lepomis machrochirus),* rainbow trout (*Oncorhynchus mykiss*), the invertebrate water flea *(Daphnia magna),* a chironomid (*Chironomus tentans*), aquatic vascular plants (*Lemna* sp.), and a green alga *(Pseudokirchneriella subcapitata)*, as well as diatoms, snails, and the plant and zooplankton communities found in outdoor microcosms.

Based on the Environment Canada definition of inherent toxicity (T_i) and the available data, PFOA is not inherently toxic. The available acute and chronic aquatic toxicity data for freshwater organisms indicate that PFOA is of low to medium concern for aquatic toxicity based on an evaluation scheme used by the U.S. Environmental Protection Agency. No data are available to assess the aquatic toxicity of PFOA to marine species (other than marine bacterium). There are also no PFOA toxicity test data available for either terrestrial wildlife or avian species.

This review also examined the literature for the levels of PFOA measured in environmental samples from around the world. Measurements were found for abiotic (outdoor air, soil, sediment, sewage sludge and effluent, landfill effluent, ground water, fresh water and salt water) and biotic (invertebrate, freshwater fish, plankton, shellfish, saltwater fish, reptile, bird and mammal) samples. The amount of PFOA found in the environment is relatively small. Current analytical methods make it possible to detect extremely low concentrations (i.e., parts-per-trillion to low parts-per billion range) in various environmental matrices. The first reports of PFOA in environmental samples in 1999 have been followed by reports using continuously improving analytical sensitivity, hence the number of non-detects is being replaced by measurable, but very small amounts being detected. Although the total number of environmental samples analyzed is growing, there currently are not enough data in any one matrix with significant samples to clearly define temporal or geographical trends among the various environmental media (including biota). Continuing studies, which incorporate more defined sampling strategies employing currently available analytical technology, should help define temporal / geographic trends. The data available to date do not seem to indicate that PFOA collects in any environmental media other than the aqueous phase of the aquatic environment, which appears to be the likely sink.

Analytical methods for the determination of PFOA in various matrices continue to evolve. Improving sensitivity of analytical instrumentation allows for lower and lower instrumental detection limits. Sampling and sample preparation methodologies used with the improving instrumental methods often are not well characterized, leaving the overall method sensitivity, precision, and accuracy unknown. It is difficult to make comparisons between literature reports, especially over time, since details such as types of standards, methods for determining LOD and LOQ, spike recovery and blank types and results are not available or are defined inconsistently. Generally the reports at the higher levels are probably reliable. At lower levels, however, analytical issues concerning reporting limits, blanks, standards, and representativeness of sample need to be addressed.

Introduction / Purpose

This white paper is a six month follow-up to DuPont Report: DuPont-17709 "Review: Perfluorooctanoic Acid in the Environment" issued on June 30, 2005. The sources for review included public records, company records, journals, books, and meeting abstracts (e.g., SETAC, FLUOROS, and DIOXIN meetings) up to January 15, 2006.

The objective of this white paper was to provide an updated literature review of information found on PFOA that covers:

- Environmental Fate
- Bioaccumulation
- Environmental Toxicity
- Environmental Concentrations
- Analytical Methodology

As part of this review, the available information for PFOA was compared against international PBT criteria (see page ix, Table 1).

This review of PFOA in the environment is based on findings from a literature search on perfluorooctanoic acid ($C_8F_{15}O_2H$), perfluorooctanoate anion ($C_8F_{15}O_2^-$), and salts of perfluorooctanoic acid ($C_8F_{15}O_2H$). This review is limited to PFOA found in the environment and does not include any evaluation of potential PFOA precursors nor potential PFOA sources.

Purpose / Objective Literature Cited

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Purpose / Objective Appendix (Table 1)

Table 1: International PBT Criteria

Criteria	Persistence (Half-life in:)	Bioaccumulation	Toxicity	Reference
Environment Canada Toxic Substances Management Program (TSMP) Criteria for the Selection of Substances for Virtual Elimination	Air > 2 days; Water > 6 months; Sediment > 1 yr; Soil > 6 months	BAF or BCF > 5000 or Log K_{ow} > 5	A substance is considered toxic if it meets or is equivalent to the definition of "toxic" found in the Canadian Environmental Protection Act (CEPA), as determined through a systematic, risk-based assessment. CEPA states: "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."	Environment Canada 1999
Environment Canada Domestic Substances List (DSL)	Air > 2 days; Water > 182 days; Sediment > 1 yr; Soil > 182 days	BAF or BCF > 5000 or Log K_{ow} > 5	Inherent Toxicity - Acute / Chronic for algae, invertebrates, fish: LC50(EC50) <= I mg/L NOEC <= 0.1 mg/L	Environment Canada 2003
EU PBT criteria	Marine Water > 60 days; Fresh Water > 60 days; Marine Sediment > 180 days; Freshwater sediment > 180 days	BCF > 5000	Chronic NOEC < 0.01 mg/L or CMR or endocrine disrupting effects	EU-TGD 2003
EU vPvB criteria	Marine Water > 60 days; Fresh Water > 40 days; Marine Sediment > 180 days; Freshwater sediment > 120 days	BCF > 5000	Not Applicable	EU-TGD 2003
Stockholm Convention	Water > 2 months; Soil > 6 months; Sediment > 6 months	BAF or BCF > 5000 or Log Kow > 5	Evidence of adverse effect on human health or the environment or toxicity characteristics indicating potential damage to human health or environment	UNEP 2001
US EPA TSCA New Chemicals Program Policy for PBTs: Controls[1]	> 2 months	$\geq$ 1,000 + MW <1,000 and cross-sectional diameter < 20 x 10^{-8} cm	Toxicity data based upon level of risk concern	US EPA 1999
US EPA TSCA New Chemicals Program Policy for PBTs: Ban pending[2]	> 6 months	$\geq$ 5,000 + MW <1,000 and cross-sectional diameter < 20 x 10^{-8} cm	Toxicity data based upon level of risk concern	US EPA 1999

1: Testing and exposure/release controls required

2: Commercialization denied except if testing may justify removing chemical from "high risk concern".

1.0 Environmental Fate

1.1 Physical-Chemical Properties

Surfactants have a hydrophilic head group compatible with water and a hydrophobic tail, which repels water. The surfactant orients itself at the water-air interface with its hydrophilic part directed toward water and the hydrophobic tail pointed toward air. In water, surfactant molecules associate to form micelles or aggregates. The hydrophobic tails of the surfactant molecules form the interior of the micelle and the hydrophilic head groups are exposed to water (Kissa, 2001a).

Perfluorinated surfactants are remarkably stable. Their outstanding thermal and chemical stability permits applications under conditions, which would be too severe for conventional hydrocarbon-based surfactants. The very strong C-F bond is stable to acids, alkali, oxidation, and reduction, even at relatively high temperatures. The unusual properties of fluorosurfactants arise from the unique properties of elemental fluorine: high oxidation potential; high ionization energy, high electron affinity, high electronegativity of covalently bonded fluorine, and fluorine is very difficult to polarize (Kissa, 2001b).

A summary of the physical-chemical properties for perfluorooctanoic acid (PFOA) and ammonium perfluorooctanoate (APFO) can be found in Appendix A: Table 1. Considering properties such as the vapor pressure, water solubility, pKa, critical micelle concentration, and surface tension, PFOA and APFO will likely most often be found in the environment in the dissociated form (essentially as an anionic surfactant: $C_8F_{15}O_2^-$), will be non-volatile, and associated with water.

In aqueous solutions, individual molecules of PFOA anion loosely associate on the water surface and partition between the air / water interface. Water solubility has been reported for PFOA but it is unclear whether these values are for a microdispersion of micelles rather than true solubility. Due to these same surface-active properties of PFOA, it is anticipated that PFOA will form multiple layers in octanol/water. Therefore, an n-octanol/water partition coefficient cannot be determined. (US EPA 2003).

Fluorosurfactants lower the surface tension of aqueous systems below 20 mN/m, substantially lower than hydrocarbon surfactants. The concentration of fluorinated surfactant required to achieve these low surface tensions is 5-10 times less than would be required for hydrocarbon- or silicon-based surfactants if they could achieve this low surface tension. The “phobe” of fluorosurfactants is both hydrophobic and lipophobic (Taylor 1999). This characteristic also accounts for why a Log K_{ow} measurement of perfluorosurfactants is difficult and more importantly not relevant for predicting how fluorosurfactants may partition in the environment.

Three studies (Appendix A: Table 2) were found in the literature to address adsorption/desorption of APFO. These studies (3M Company 1978a; DuPont 2000; and Association of Plastic Manufacturers in Europe 2003) indicated low adsorption to soils and/or sludge, clay, sand, and sediments suggesting a potential for mobility in soils.

1.1.1 Physical-Chemical Properties Uncertainty

To better understand potential mechanisms for transport or distribution of PFOA in the environment, it would be helpful to get an understanding of whether or not perfluorinated anionic surfactants such as PFOA (PFO anion):

- Have a tendency to accumulate in the water surface microlayer (i.e., surface films).
- Can be potentially sequestered in solid matrices (soil, sediments, sludge) via an "aging phenomenon".
- Are associated with just the water phase of solid matrices rather than adsorbed to solid matrices (i.e., soil, sediments, sludge).
- Have physical-chemical properties that enable presence in aerosols – (e.g., aerosols formed by wave and winds action on ocean surface microlayer films) or have pKa values that enable measurable sublimation from water surface microlayers.

Furthermore, considering that PFOA is a mix of both linear and branched forms, there is a need to determine whether or not the linear and branched isomers have differences in physical-chemical properties, which may result in differences in environmental transport/distribution and ultimate fate in the environment.

1.2 Persistence

The recalcitrant nature of perfluorinated compounds is attributed in part to the rigidity of the perfluorocarbon chain as well as the strength of the C-F bond (Moody and Field 1999; Smart 1986). In 1997, Key *et al.* reported that monofluorinated carboxylic acids can undergo hydrolytic defluorination, reductive defluorination, and decarboxylation, but they had no evidence of PFOA transformation.

1.2.1 Biodegradation

Ten studies were found in the literature covering the biodegradation potential of PFOA (Appendix A: Table 3 a, b, c).

There were four Biochemical Oxygen Demand / Chemical Oxygen Demand (BOD/COD) biodegradation studies reported by the 3M Company between 1977 and 1987. Three of the studies (3M Company 1977; 3M Company 1985; 3M Company 1987a) were inconclusive because they reported unexpectedly high BODs, which may be indicative of impurities or other quality issues with the studies. In another BOD/COD study (3M Company 1980a), BOD levels indicated no biodegradability in a 20-day study, however with inconsistent results with the COD data, it was not possible to determine a reliable BOD/COD value.

The biodegradation determination based on BOD/COD ratios was difficult to interpret due to the COD methods apparently yielding incomplete oxidation resulting in two studies having BOD > COD values (3M Company, 1977 and 3M

Company, 1985). Typically, COD for raw domestic wastewater is about 2.5 times the 5-day BOD.

3M Company conducted an Alkylbenzenesulfonate / Linear (secondary) Alkylbenzenesulfonate (ABS/LAS) shake culture test (3M Company 1978b) that indicated no biodegradation of APFO after 78 days. A specific concern with this test was that the LAS positive control chemical, which typically completely degrades within 10 days, did not show appreciable biodegradation until day 37, thus indicating that biodegradation conditions may not have been optimal for the full duration of the study.

In 1996, the biodegradation of APFO was studied using a biodegradability bottle assay test with aerobic bacteria previously shown to have a broad range of degradative capabilities (DuPont 1996). This study was inconclusive due to the PFOA analysis lacking sensitivity.

DuPont conducted a Modified Sturm test (DuPont 1997) on APFO. The analysis was limited to CO_2 evolution and on this basis, 13% biodegradation was observed. The conclusion was that the alkyl portion (COO-) may have been transformed, but in the absence of specific analysis of PFOA, this could not be confirmed.

3M Company conducted an Inherent Biodegradability test – Zahn-Wellens/EMPA test (3M Company 2001a) that indicated no measurable biodegradation of PFOA for the duration of the test. This test is typically conducted for 28 days, but the 3M study was limited to 18 days with measurements only taken at day 0 and day 18.

Laboratory scale wastewater closed-loop bioreactors for aerobic and anaerobic treatment were used to assess the biodegradation potential of APFO (Schroder 2003; Meesters and Schroder 2004). The results indicated that under aerobic conditions PFOA was not biodegraded, whereas, under anaerobic conditions PFOA could no longer be detected after 25 days. However, elevated concentrations of fluoride ions were not observed, so degradation of the hydrophobic fluorine-containing moiety was not indicated. This study also indicated no adsorption onto glass walls of the reactor. The study concluded that the whereabouts of the fluorinated segment of the anionic perfluorinated surfactant (i.e., PFOA) remained unknown. Thus, it is possible that perhaps only the alkyl portion (COO-) of PFOA may have been transformed under anaerobic conditions, and the perfluorinated segment may have been adsorbed to the sludge and/or sequestered in the sludge matrix.

An aquatic mesocosm study was conducted at the University of Guelph (Richards *et al.* 2001) and the initial results indicated that PFOA was persistent in the water column with no significant degradation observed 35 days post application. A second paper (Hanson *et al.* 2005) discussing a microcosm study at the University of Guelph Microcosm Facility indicated that there were no changes in the concentration of PFOA at the 0.3, 1, and 30 mg/L treatments over a 35-day field study.

Wang *et al.* 2005 noted that decarboxylation of ^{14}C-PFOA by activated sludge was observed at a very slow rate (~0.5% over 63 days), suggesting that PFOA may potentially be biodegraded very slowly by microorganisms and such degradation may not be detected by conventional LC/MS/MS analysis. However, further study is needed to be conclusive.

1.2.2 Direct Photolysis / Indirect Photolysis

Four studies were found in the literature that address the direct and/or indirect photolysis of ammonium perfluorooctonoate (Appendix A: Table 4).

A direct photolysis study (3M Company 1979) showed that no photodegradation products were detected in a 30-day study using simulated sunlight (24 h/day), thus indicating that PFOA, ammonium salt does not undergo direct photolysis.

In 2001, an Indirect Photolysis Screening test (US EPA OPPTS: 835.5270) and "Phototransformation of Chemicals in Water – Direct and Indirect Photolysis" tests were conducted to assess the potential for direct and indirect photolysis of perfluorooctanoic acid, ammonium salt (3M Company 2001b). Neither direct nor indirect photolytic decomposition of PFOA were observed based on the loss of starting material, nor were any of the hypothesized degradation products detected above their limit of quantitation (LOQ). Using an iron oxide (Fe_2O_3) photoinitiator matrix model, the PFOA half-life was estimated to be >349 days.

There were two papers that reported photochemical approaches for decomposing PFOA but these studies were done under conditions that were not environmentally relevant. The studies were designed to develop techniques for decomposing stationary sources of PFOA. In a direct photolysis study, Hori *et al.* (2004) showed 89.5% loss of the initial PFOA after 72 hours of irradiation with a xenon mercury lamp in an aqueous solution of PFOA under 0.48 MPa of O_2 at room temperature. They also demonstrated complete PFOA decomposition after 24 hours of irradiation using a tungstic heteropolyacid photocatalyst under similar conditions as the direct photolysis study. Hori *et al.* (2005) reported photochemical decomposition of PFOA in water by use of persulfate ion ($S_2O_8^{2-}$). In this study, PFOA was completely decomposed by a photochemical system with 50 mM $S_2O_8^{2-}$ and 4 hours of irradiation from a 200-W xenon-mercury lamp.

1.2.3 Hydrolysis

Only one study on the hydrolysis of PFOA was found in the literature (3M Company 2001c). In this study, hydrolysis was assessed over 109 days at pH 5, 7, and 9 at 50^{o}C and the results were extrapolated to 25^{o}C. Based on the results, the hydrolytic half-life of PFOA was estimated to be >97 years. Although, 6 pH levels were included in the study, pH levels of 3.0 and 11.0 failed to meet the data quality objective for matrix spike recovery and pH 1.5 was rejected because ion pairing led to artificially low

concentrations. However, pH levels of 5, 7, and 9 had results that indicated no clear dependence of the degradation rate of PFOA on pH.

1.2.4 Persistence Uncertainty

A limited number of studies on the biodegradation potential of APFO have been reported, but most of the cited studies had high levels of uncertainty, so there is currently not a definitive answer on the biodegradation potential of APFO. These uncertainties include:

- BOD/COD testing of mixtures rather than discreet chemical;
- unexpectedly long adaptation of "readily biodegradable" controls before appreciable biodegradation observed;
- lack of PFOA-specific analysis;
- short duration of biodegradability studies.

Furthermore, all of the biodegradation studies cited in this review have used an inoculum from activated sludge sources or cell cultures, whereas, there have been no reported studies in other relevant environmental matrices such as soils or sediments. It is noteworthy that two of the reviewed biodegradation studies have indicated a potential for primary biotransformation in anaerobic wastewater sludges.

In addition to the direct and indirect photolysis studies reviewed in this white paper, research on the potential for photolysis of PFOA present in aerosols / vapor phase and/or associated with air particulates would be helpful for understanding the potential mechanisms of transport or distribution of PFOA in the environment.

For hydrolysis, there was only one study found in the literature and hydrolysis was evaluated using only pH 5, 7, and 9. The potential hydrolysis at pH < 5 or > 9 has not been evaluated, so potential hydrolysis at extreme pH levels is still uncertain.

1.3 Fate in the Environment

1.3.1 Air

As noted in the Physical-Chemical Properties section above, under most circumstances PFOA will exist in the dissociated form and will be non-volatile. The expectation is that PFOA found in air would be removed from air via a precipitation event (e.g., rain, snow, etc.). Based on the available literature, it appears that PFOA will meet the international criteria (see page ix, Table 1) for persistence in air.

Berger *et al.*, 2005 analyzed fluorinated alkyl compounds in air samples from England and they observed that PFOA exhibited the highest concentrations of all fluorinated analytes on aerosol samples.

When air was bubbled through a water solution of PFOA, Waterland *et al.*, 2005 observed that foams are significantly enriched in PFOA vs. solution. Based on this

data, the authors raised the following questions – Do sea foams and sea mists contain PFCAs and can PFCAs be found on marine aerosols?

1.3.2 Water (i.e., surface water and ground water)

It is likely that water will be the predominant environmental compartment where PFOA is found. Based on the available literature, it appears that PFOA will meet international criteria (see page ix, Table 1) for persistence in water.

1.3.3 Wastewater Treatment Plant

The 3M Company reported four studies on activated sludge respiration inhibition (Appendix A: Table 6). These studies (3M Company 1980b; 3M Company 1987b; 3M Company 1990; 3M Company 1996) indicated that APFO is not expected to inhibit activity of activated sludge.

The biodegradation studies described above generally indicate that aerobic biodegradation is unlikely under typical wastewater treatment conditions.

To better understand the behaviour of fluorochemicals through a wastewater treatment, Schultz *et al.* 2005 conducted a field study at a full-scale municipal wastewater treatment plant to determine the mass flows in wastewater and sludge. They observed that perfluoroalkyl carboxylates were overall removed by the wastewater treatment plant, whereas perfluoroalkyl sulfonates were found to increase significantly(~ 200%) in the plant mass balance (30 days) and fluoroalkylsulfonamide acetic acids were also found to increase by at least 300% throughout the sludge treatment process within a residence time of a year.

Section 4.1.4 of this report provides a summary of PFOA concentrations in sewage sludge and effluent. In summary, these studies indicate that PFOA tends to have higher concentrations in effluent versus PFOA concentrations found in sludge. It is likely that the PFOA concentrations observed in sludge are associated with the aqueous phase of sludge versus the sludge solids.

1.3.4 Soil

Degradation potential is unknown. The extent of mobility in soil will depend on soil type.

1.3.5 Sediments

Degradation potential is unknown. Section 4.1.3 of this report provides a summary of PFOA concentrations in sediment. In summary, these studies indicate that PFOA existed mainly in the dissolved-phase in water and that the amount of PFOA deposition to bottom sediment was negligible. Therefore, it is unlikely that sediment is a significant environmental compartment for PFOA.

1.3.6 Fate in the Environment Uncertainty

It is unclear whether or not PFOA may be transported in air via aerosols. There is growing interest in the presence of surfactants in atmospheric aerosols (Ellison *et al.* 1999; Murphy *et al.* 1998; Latif and Brimblecombe 2004). A hypothesis is that PFOA may be present in the marine surface microlayer and enter the atmosphere after being aerosolized via wave action and winds. Furthermore, the observations of Berger et al., 2005 that PFOA was dominant in aerosol samples collected in England also raises questions about the role of aerosols in regards to the potential long-range transport of PFOA and/or widespread distribution of PFOA in the environment..

In water, there is still some uncertainty regarding the potential for long-term ultimate biodegradation or at least primary biotransformation under varying environmental conditions (e.g., anaerobic conditions in groundwater).

In wastewater, no available biodegradation data were found to assess what may happen to PFOA under the conditions found in an anaerobic digester. It is not clear if PFOA found associated with sludge is actually part of the water phase in sludge or there is actual adsorption (i.e., perhaps by electrostatic interaction) or perhaps sequestration (aging) within the sludge matrix over time.

In soils and sediments, no data was found to assess the biodegradation potential of PFOA under aerobic or varying anaerobic conditions in soil or sediments over time. Considering the physical-chemical properties of PFOA, the potential for sequestration (“aging”) within the soil or sediment matrix needs to be evaluated to address bioavailability in soils or sediments as well as potential for PFOA to migrate through the soil vadose zone to groundwater. It is not clear if PFOA found associated with soils and sediments is actually part of the water phase in soil and sediment or if there is actual adsorption (i.e., perhaps by electrostatic interaction).

Furthermore, considering that PFOA is a mix of both linear and branched forms, there is a need to determine whether or not the linear and branched isomers have differences in physical-chemical properties, which may result in differences in environmental transport/distribution and ultimate fate in the environment.

1.4 Environmental Fate Conclusions

Based on studies in the available literature, PFOA will meet international criteria (see page ix, Table 1) for persistence based on expected half-lives of PFOA via biodegradation, hydrolysis, and photolysis under environmentally relevant conditions. It is anticipated that water will be the predominant environmental compartment in which PFOA resides. In regard to sludges, soils, and sediments, the expectation is that adsorption will be very limited and any PFOA associated with these environmental matrices will likely be found in the water phase of sludges, soils, and sediments and/or perhaps weakly adsorbed by electrostatic interactions.

However, there are still significant uncertainties concerning the environmental fate of PFOA including: 1) sources of PFOA in the environment; 2) potential for biotransformation in soil and sediments under varying environmental conditions and anaerobic sludges; 3) transport / distribution mechanisms; 4) potential for oceans to be predominant sinks; 5) role of aerosols in transport and distribution of PFOA in the environment.

1.5 Environmental Fate Literature Cited

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1.6 ENVIRONMENTAL FATE: APPENDIX A

(Tables 1-6)

Table 1: Summary of Physical Chemical Properties of Perfluorooctanoic Acid (PFOA) and Ammonium Perfluorooctanoate (APFO)

Chemical Name	Perfluorooctanoic acid (PFOA)	Ammonium Perfluorooctanoate (APFO)
Chemical Formula	$C_8HF_{15}O_2$[1]	$C_8H_4F_{15}NO_2$[1]
CAS Registry No.	335-67-1[1]	3825-26-1[1]
Molecular Weight	414.1 g/mole[1]	431.1 g/mole[1]
Appearance	solid, white pungent odor[1]	solid, white[1]
Melting Point	54.3°C[1]; 52-54°C[3]	157 to 165°C[1]
Sublimation Point	40°C (slight)[1]	130°C[1]
Boiling Point	188°C (at 760 mm Hg)[1]; 189°C[3]	Decomposes[1]; Sublimes at 130°C[2]
Vapor pressure	0.02 mm Hg (at 20°C)[1]; 128 Pa at (59°C)[5]; 7.0 E1 Pa[6]	6×10^{-5} mm Hg (at 20°C)[1]; 7×10^{-5} mm Hg (at 20°C)[2]; <1.3 E-3 / 9.2 E-3 Pa[6]
Density	1.8 g/cm^3 (at 20°C)[1]	0.6 to 0.7 g/mL[2]
Water Solubility	3.4 g/L (at 20°C)[1]; 9.5 g/L[6]	50% at room temperature[1]; >5.00E2 g/L[6]
Acid-Dissociation Constant	1.5 to 2.8 (expressed as pKa)[1]	3.66 (expressed as K)[1]
pH	2.6 (1 g/L at 20 °C)[1]	4-7 (2% solution)[2]
Henry's Law Constant (K_H) (calculated)	4.6 E-6[6] atm*m^3*mol^{-1}	<1.1 E-11 / 7.8 E-11 atm*m^3*mol^{-1}
Octanol-Water Partition Coefficient (Kow)	Cannot be determined (surfactant)[1]	Cannot be determined (surfactant)[1]
Photodegradation		Half-life > 349 days[1]
Hydrolysis	Half-life > 97 years (at 25°C)[1]	
Critical Micelle Concentration	8.7 to 9.0 mmoles/L[4]	
Surface Tension	15.2 dynes/cm[4]	

1: Environ International Corporation 2004
2: Griffith and Long 1980
3: Kirk-Othmer Enceyclopedia of Chemical Technology 1994
4: Moody and Field 2000
5: Kaiser et al. 2005
6: Heckster and de Voogt 2002

Table 2: Summary of Soil Adsorption Studies of Ammonium Perfluorooctanoate (APFO)

Test Matrix / Texture	Test method	% adsorption	Kd	Koc	Conclusions	Reference
Soil: Brill sandy loam	Adsorption-desorption study using the approach recommended by US EPA for pesticide registration			14	Low adsorption to soil and sludge; High mobility in soil	3M Company 1978a
Kaolin and Montmorillonite clays; peat moss; sand; 3 soils; 2 sediments	US EPA OPPT method: Sediment and soil adsorption/desorption isotherm	Clays: 0-35%; Sand: 0-7%; Peat moss: 77-87%; Soils: 0-46%		Soils: 4.2 E-2 to 1.2 E-1; Sediments: 8.8 E-2 to 0	Low adsorption to clay, sand, soil and sediment; High mobility in soil; High adsorption to peat moss	DuPont 2000
4 soils; Silt clay loam, sandy clay loam, sandy loam, loam; 1 sludge: Sandy loam	OECD 106 Adsorption-desorption using a batch equilibrium method	Soils: 27.8 to 88.9%; Sludge: 69.5-87.3%	Soils: 0.41 to 8.86 mL/g; Sludge: 12.6 to 36.8 mL/g	Soils: 48.9 to 229 mL/g; Sludge: 20.5 to 59.6 mL/g	Low adsorption to soil and sludge; High mobility in soil	APME 2003

Table 3a: Summary of BOD/COD Biodegradation Studies for PFOA

Test Substance	Test Method	Study Duration	Conditions	Inoculum	Conclusions	Literature Cited
Ammonium Perfluorooctanoate; FC-143	COD/BOD study; Method not noted	14 days	aerobic	Not noted	No biodegradation at day 5; day 14 result inconclusive (BOD 2-3X > COD); Study procedures and raw data not found; Inconclusive	3M Company 1977
Ammonium Perfluorooctanoate; FC-143	COD/BOD study; Method not noted	20 days	aerobic	Activated sludge collected from 3M Chemolite Facility, Cottage Grove, MN	Based on BOD, no biodegradation observed; COD data questionable; Summary sheet noted duplicate results not consistent; Weight of evidence - no biodegradability	3M Company 1980a
Perfluorooctanoic acid; PFOA; FX-1001	COD/BOD study; Method not noted	20 days	aerobic	Activated sludge collected from 3M Chemolite Facility, Cottage Grove, MN	BOD results exceptionally high - purity questionable; days 10 & 20 were more than 7X > COD; Raw data not found; Inconclusive	3M Company 1985
Ammonium Perfluorooctanoate; FC-126	COD/BOD study; EPA Standard Method 507/508A	20 days	aerobic	Not noted	BOD results unexpectedly high likely due to mixture components (78-93% test substance); Inconclusive	3M Company 1987

Table 3b: Summary of Ready/Inherent Biodegradation Studies for PFOA

Test Substance	Test Method	Study Duration	Conditions	Inoculum	Conclusions	Literature Cited
Ammonium Perfluorooctanoate; FC-143	Shake culture test modeled after the Soap and Detergent Association's presumptive test for determination of ABS/LAS biodegradability	2.5 months	aerobic	Activated sludge collected at 3M Chemolite Facility, Cottage Grove, MN; 3M Decatur facility, Decatur, AL; and Metro Wastewater treatment Plant, St. Paul, MN	No biodegradation of FC-143 observed; However, Linear Alkyl sulfonate (LAS) control, which is typically rapidly "readily biodegradable" did not show appreciable biodegradation until day 37, so there may be some concerns about the robustness of the test.	3M Company 1978b
PFOA	Modified Sturm Test (OECD 301 B)	28 days	aerobic	Activated sludge from Wilmington, DE POTW	Not "Readily Biodegradable", but 13% biodegradability was observed at day 28.	DuPont 1997
Ammonium Perfluorooctanoate	EPA OPPTS 835.3200: Zahn Wellens/EMPA Test	18 days	aerobic	Activated sludge collected at Metro Wastewater treatment Plant, St. Paul, MN	Not measurably degraded after 18 days; This test is typically conducted for 28 days - 18 days may be viewed as insufficient time to induce conditions needed for potential biodegradation.	3M Company 2001a

Table 3c: Summary of Other Biodegradation Studies for PFOA

Test Substance	Test Method	Study Duration	Conditions	Inoculum	Conclusions	Literature Cited
Ammonium Perfluorooctanoate	Biodegradability bottle assay tests with aerobic bacteria previously shown to have a broad range of degradative capabilities	12 hours	aerobic	9 different strains of bacteria	Inconclusive; Analytical analysis lacked sensitivity	DuPont 1996
Perfluorooctanoic acid (PFOA); Fluorad FC-143	Laboratory scale reactors for aerobic and anaerobic treatment	25 days	aerobic and anaerobic	Aerobic: STP effluent mixed with effluent from pre-settling tank of Aachen-Soers municipal STP; Anaerobic: effluent from stabilization tank of same STP	Aerobic: No biodegradation observed; Anaerobic: PFOA no longer detected after 25 days; increased concentrations of fluoride ions were not observed; no adsorption on glass walls of reactor; results indicate potential transformation of COO- but whereabouts of perfluorinated segment was not determined.	Schroder 2003; Meesters and Schroder 2004
Perfluorooctanoic acid (PFOA)	Aquatic mesocosm studies at University of Guelph Microcosm Facility	35 days	aerobic	none	Persistent in water column; No significant degradation after 35 days	Richards et al. 2001; Hanson et. al., 2005

Table 4: Summary of Photodegradation Studies for Ammonium Perfluorooctanoate (APFO)

Test Substance	Test method	Exposure period	Conclusions	Reference
Ammonium Perfluorooctanoate; FC-143	Direct photolysis procedure described in Federal Register (Vol. 43, No. 132-Monday, July 10, 1978) by US EPA	30 days	No photodegradation was detected after 30 days.	3M Company 1979
Perfluorooctanoic acid, ammonium salt	Based on OPPTS: 835.5270 "Indirect Photolysis Screening Test" (1998) and OECD Draft document "Phototransformation of Chemicals in Water - Direct and Indirect Photolysis." (2000).	69.5-164 hrs	Neither direct nor indirect photolytic decomposition of PFOA were observed based on loss of starting material; Estimated minimum indirect photolytic half-life > 349 days.	3M Company 2001b
Perfluorooctanoic acid (PFOA)	Not environmentally relevant; Tested direct photolysis, H_2O_2, heteropolyacid photocatalyst using aqueous solution of PFOA under 0.48 mPa O_2 at RT.	24-72 hrs	Direct photolysis: 89.5% of the initial PFOA decomposed after 72 hours with irradiation of an aqueous solution of PFOA under 0.48 mPa of O_2 at room temperature; Tungstic heteropolyacid photocatalyst: Under similar conditions as the direct photolysis study, led to complete PFOA decomposition after 24 hours of irradiation.	Hori et al. 2004
Perfluorooctanoic acid (PFOA)	Not environmentally relevant; Tested direct photolysis, H_2O_2, heteropolyacid photocatalyst using aqueous solution of PFOA under 0.48 mPa O_2 at RT.	4 hrs	PFOA was completely decomposed by a photochemical system with 50 mM $S_2O_8^{2-}$ and 4 hours of irradiation from a 200-W xenon-mercury lamp.	Hori et al. 2005

Table 5: Summary of Hydrolysis Study for Ammonium Perfluorooctanoate (APFO)

Test Substance	Test method	pH levels	Conclusions	Reference
Perfluorooctanoic acid, ammonium salt	Based on OPPTS: 835.2110: "Hydrolysis as a function of pH": US EPA OPPTS publication no. 712-C-98-057.	5, 7, and 9	Estimated Hydrolytic half-life of PFOA > 97 years	3M Company 2001c

Table 6: Summary of Activated Sludge Respiration Inhibition Studies for Ammonium Perfluorooctanoate (APFO)

Test Substance	Test method	Exposure period	Conclusions	Reference
Ammonium Perfluorooctanoate; FC-143	Acute toxicity of a compound to activated sludge mixed liquor (3M method)	7 minutes	Not expected to inhibit activity of activated sludge	3M Company 1980b
Ammonium Perfluorooctanoate; FC-126	OECD 209	30 min. and 3 hrs.	Test material at 1,000 mg/L induced 38% inhibition after 3 hrs. of exposure	3M Company 1987b
Ammonium Perfluorooctanoate; FX-1003	OECD 209	30 min. and 3 hrs.	3-hr. EC50 for activated sludge respiration inhibition was determined be >1,000 mg/L.	3M Company 1990
Ammonium Perfluorooctanoate; FC-1015-X	OECD 209	30 min. and 3 hrs.	3-hr. EC50 for activated sludge respiration inhibition was determined be >3,320 mg/L.	3M Company 1996

2.0 Bioaccumulation

2.1 Bioconcentration/Bioaccumulation

Bioaccumulation is the process in which a substance accumulates in an organism via uptake from both food and water as a result of all processes that affect compound adsorption, distribution, metabolism, and elimination in the organism (Macek et al. 1979, Suedel et al. 1994). The cumulative effect of all these processes in an organism when the route of exposure is solely from water is known as bioconcentration (Macek et al. 1979, Seudel et al. 1994). Bioconcentration factors (BCF) represent the ratio of the exposure concentration in water to organism tissue residues while bioaccumulation factors (BAF) represent the ratio of the exposure concentrations in water and diet to tissue residues in the organism. Tissue residues in whole organisms are of concern in ecological risk assessments because predators typically consume entire organisms. Residue concentrations in edible tissues (e.g., fish fillets) are generally the focus of human health risk assessments.

For many hydrophobic organic chemicals, bioconcentration and/or bioaccumulation factors may be estimated from the octanol-water partition coefficient (K_{ow}) for the compound based on the assumption that hydrophobic organic chemicals preferentially accumulate in lipids. Since PFOA does not preferentially partition to lipids, the K_{ow} for PFOA is not a suitable predictor for bioconcentration or bioaccumulation. The most appropriate method of determining bioaccumulation potential for such substances is via experimental approaches.

Several studies have been completed in different laboratories to directly examine the bioconcentration and/or bioaccumulation potential of PFOA (Table 1). In a bioconcentration study conducted under static test conditions, the BCF for fathead minnows was determined to be 1.8 (3M Company, 1995). Using a flow-through test method (essentially OECD 305), the bioconcentration of PFOA in fish was tested using common carp (*Cyprinus carpio*) at two nominal exposure concentrations, 5 and 50 ug/L (Daikin 2000). Analyses were performed on water and fish extracts using liquid chromatography-mass spectrometry (LC-MS). No mortality or abnormalities in fish behavior or appearance were reported during the study. Mean measured concentrations of the test substance in water were used to calculate the bioconcentration factor (BCF). For the highest exposure concentration (nominal 50 ug/L), the average steady state BCF (based on study days 6-28) was reported to be 3.1. For the lowest exposure concentration (nominal 5 µg/L), the maximum BCF was determined to be 9.4 after day 16. The BCF fell to $\leq$ 5.1 by day 28. However, tissue residue concentrations in fish in the 5 µg/L nominal exposure concentration were at or below the determination (i.e., quantitation) limit at day 28; therefore, the authors indicated that no steady state BCF could be determined for this exposure level (i.e. tissue concentration < LOQ).

In a recent field investigation in Japan (Morikawa et al., *in press*), BCF values for two species of turtles, *Trachemys scripta elegans* and *Chinemys reevesii*, were reported to be less than 4 based on measured PFOA concentrations in the rivers from which the turtles were collected and in the turtle plasma. A total of 94 turtles were evaluated in

conjunction with ambient water samples; the authors also reported that the BCF values in turtles declined as the PFOA concentration increased in the ambient water samples.

Additional peer reviewed data to support that PFOA neither bioaccumulates nor biomagnifies in the food chain can be found in laboratory studies by Martin *et al.* (2003a,b). In two separate laboratory experiments, juvenile rainbow trout (*Oncorhynchus mykiss*) were exposed either via water or diet containing PFOA as part of a mixture of a homologous series of perfluoroalkyl carboxylates and sulfonates. Trout were exposed to the test substances for 32 days followed by a 41-day depuration period (Martin *et al.* 2003a,b). The carcass bioconcentration factor (BCF) for PFOA was determined to be 4.0 ± 0.6 (Martin *et al.* 2003a) while the blood and liver BCF values were 27 and 8, respectively. The carcass bioaccumulation factor (BAF) for PFOA was determined to be 0.038 ± 0.006 (Martin *et al.* 2003b).

In a recent study, Martin *et al.* (2004a) measured PFOA in various organisms from a food web of Lake Ontario. By accounting for the known diet composition of lake trout, it was shown that bioaccumulation did not occur for PFOA at the top of this food web nor did biomagnification occur through successive trophic levels of the food web. Similar observations were reported (Tomy *et al.* 2004) for an eastern Arctic marine food web where PFOA did appear to biomagnify between individual feeding relationships (BMF values of 0.04 – 2.7) but not through the entire food web. However, it is important to note that in their calculation of BMF values, the authors utilized one-half the limit of detection for analytical non-detect values.

In a similar fashion, data from another Great Lakes food chain (Kannan et al. 2005) and Greenland and the Faroe Islands (Bossi et al. 2005a) provide support for the hypothesis that PFOA does not biomagnify through foodchains.

Environmental monitoring studies indicate PFOA can occasionally be detected in wildlife, including polar bear and arctic foxes (Martin *et al.* 2004b; De Silva and Mabury 2004) and occasionally in birds (Giesy and Kannan 2001). Temporal trends have also been investigated in several studies. Tomy et al. (2005) reported an increase in tissue residues of PFOA in beluga whales from SE Baffin Island over the period from 1982 to 2002. However, evaluation of this data indicates no trend in the data from 1982 through 1995. No samples were analyzed for the period between 1995 and 2002 but the PFOA concentrations in the 2002 samples were greater than concentrations in the 1995 samples. While the data between 1995 and 2002 may be suggestive of a temporal trend, samples from additional time points will be necessary to confirm or refute any trend. In a study on temporal trends, the concentrations of PFOA in the Baltic Sea marine environment were measured using archived guillemot eggs, *Uria aalga* (Holmstrom *et al.* 2005). Egg samples collected from Stora Karlsö (Sweden) between 1968 and 2003 were obtained from an environmental specimen bank and concentrations of PFOA were analyzed using high pressure liquid chromatography with electrospray ionization tandem mass spectrometry (HPLC ESI-MS/MS). PFOA was not detected in any of the samples at the LOD of 3 ng/g; consequently no trend existed in PFOA concentrations over the 35-year period represented by these egg samples.

Similarly, in an evaluation of ringed seal liver residues from western and eastern Greenland over the period from 1982 to 2003, Bossi et al. (2005b) reported that PFOA concentrations were below the minimum detection limit (MDL, 1.2 ng/g) for PFOA in all samples (n= 30 for western Greenland, n = 36 for eastern Greenland).

The EU hazard classification and labelling scheme indicates that if the BCF for a compound is 100 or more the material may be classified as R53 (EEC 1967). The PFOA BCF is at least an order of magnitude lower than this limit. The Globally Harmonised System on Classification uses a BCF of 500 as the lower limit for classification (UNEP, 2003). Regulatory classification schemes such as the EU hazard classification and labelling scheme and the EU PBT-assessment approach indicate that PFOA is not bioaccumulative.

In the EU PBT-assessment approach, environmental parameters are used as criteria for identification of a substance as persistent (P), bioaccumulative (B) and toxic (T). The limits for the bioaccumulation assessment are based on the BCF for a compound. If the BCF for a compound is 2000 or more the substance is categorized as bioaccumulative (B) (EU TGD 2003). If the BCF is more than 5000 the substance is categorized as very bioaccumulative (vB). The latter categorization scheme for B is also consistent with the terminology for B classification in CEPA 1999, i.e., bioaccumulative chemicals have a bioaccumulation factor greater than or equal to 5000. All available evidence indicates that PFOA is not B (bioaccumulative) based on relevant regulatory B criteria.

2.1.1 Bioconcentration/Bioaccumulation Uncertainty

The existing laboratory bioconcentration/bioaccumulation data are for freshwater fish. There are no laboratory study data for freshwater invertebrates or marine invertebrates or fish. There are also no bioaccumulation data from laboratory studies with other vertebrate species (e.g., terrestrial mammals), birds or terrestrial plants. However, levels of PFOA in organisms sampled from the environment suggest that bioaccumulation and biomagnification of PFOA are unlikely to be significant issues for wildlife species. Considering that PFOA from ECF processes are a mix of linear and branched isomers, there is a need to learn if the isomers have differences in bioaccumulation potential.

2.2 Bioaccumulation Conclusion

The available data indicate that BAF and BCF values for PFOA are below all regulatory levels that would trigger concern for bioconcentration and bioaccumulation. In addition, the available evidence indicates that PFOA does not biomagnify through the foodchain. Therefore, while PFOA appears to be environmentally persistent, PFOA is not bioaccumulative based on relevant data and regulatory B criteria.

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2.4 Bioaccumulation: Appendix A

Table 1. Laboratory Bioconcentration, Bioaccumulation and Biomagnification Data for PFOA.

Substance	Species	Bioconcentration	Bioaccumulation	Biomagnification
PFOA (NH4+)	Fathead minnow	1.8 [a]	–	—
	Rainbow trout	4 [b]	0.038[b]	< 1 [b]
	Carp	<9.4[c]	–	–
	Slimy Sculpin	–	–	TMF = 0.37 [d]
	Lake Trout	–	–	TMF = 0.58 [d]
	Various species	–	–	BMF = 0.04 – 2.7 [e,f]

a - 3M 1995
b - Martin *et al.* 2003a, b
c – Daikin 2000
d – Martin *et al.* 2004a
e – Tomy *et al.* 2004
f - values may be based on 0.5 LOD substituted for analytical non-detect values

3.0 Environmental Toxicity

3.1 Toxicity in the Aquatic Environment

3.1.1 Acute Toxicity

Most of the aquatic toxicology studies have been conducted with the ammonium salt of perfluorooctanoic acid (PFOA). PFOA is a completely fluorinated organic acid and the free acid is expected to be completely dissociated in water. The toxicity of PFOA to aquatic organisms has been investigated in numerous acute and chronic studies that are summarized in Appendices A, B, C and D. The algae species *Selenastrum capricornutum* was recently renamed *Pseudokirchneriella subcapitata* and the information in the Appendices reflects this name change although original report titles have been maintained in the reference section.

Several groups of organisms and species were tested to assess the acute toxicity of PFOA including the mixed bacterial community found in sewage sludge, the marine bacterium, *Photobacterium phosphoreum* (i.e., Microtox), the fathead minnow *(Pimephales promelas),* bluegill sunfish *(Lepomis machrochirus),* rainbow trout (*Oncorhynchus mykiss*), the invertebrate water flea *(Daphnia magna),* an insect (*Chironomus tentans*), and a green alga, *(Pseudokirchneriella subcapitata)*, as well as diatoms, snails, and the plant and zooplankton communities found in outdoor microcosms. The toxicity test endpoints in Appendices A, B, C and D are presented based on nominal test substance concentrations unless indicated otherwise. Information is also provided on the actual test substance purity in addition to citations to original source documents and the U.S. Environmental Protection Agency Administrative Record document number (e.g., U.S. EPA AR226-xxxx) if applicable.

3.1.1.1 Bacteria

The 30-minute and 3-hour EC50 (effect concentration producing 50% inhibition) values for respiratory inhibition of sludge communities ranged from >1000 mg/L to > 3330 mg/L while 30-minute EC50 values from the Microtox assay with *Photobacterium phosphoreum* ranged from 870 to 3150 mg/L (see Appendix A).

3.1.1.2 Algae

The lowest 96-hour EC50 and NOEC (no observed effect concentration) values reported from algal assays with *Pseudokirchneriella subcapitata* were 49 and 12.5 mg/L, respectively. Overall, 96-h EC50 values (based on growth rate, cell density, cell counts, and dry weights) ranged from 49 to > 3330 mg/L while NOEC values ranged from 12.5 to 430 mg/L (see Appendix A). Based on these values, U.S. EPA would classify PFOA as being of low to medium concern for acute aquatic toxicity to algae (Smrchek *et al.* 1995).

3.1.1.3 Invertebrates

Protozoa

An EC50 value of 424.1 ± 124.0 μM PFOA and dose-dependent reductions in the backward swimming response were reported from a screening study evaluating the effects of PFOA on backward swimming ability of the protozoan, *Paramecium caudatum* (Matsubara et al. 2006). The authors hypothesized that the endpoint utilized in the study was related to the potential toxicity of PFOA on ion channels and that the alteration of backward swimming behavior in *P. caudatum* was due to changes in calcium conductance induced by PFOA.

Aquatic Invertebrates

Daphnid 48-h EC50 values (based on immobilization) ranged from 126 to >1200 mg/L. The 48-h LC50 for an unidentified species of snail was 820 mg/L while the 10-day NOEC for the sediment-dwelling chironomid species, *Chironomus tentans*, was > 100 mg/L (see Appendix B). Based on these values, U.S. EPA would classify PFOA as being of low concern for acute aquatic toxicity to invertebrates (Smrchek *et al.* 1995).

Stevenson et al. (2005) reported on the effects of PFOA on the cellular *p*-glycoprotein (*p*-gp) transporter in gill tissue of the marine mussel, *Mytilus californianus*. The *p*-gp transporter has been identified in many aquatic organisms and has been suggested to function as the first line of defense against chemical exposure by binding and exporting moderately hydrophobic chemicals from the cell. The authors indicated that exposure to PFOA significantly inhibited the *p*-gp transporter, however, no specific data were presented in the abstract to support this statement.

Terrestrial Invertebrates

Effects of PFOA on the terrestrial nematode, *Caenorhabditis elegans*, were evaluated in a study by Tominaga et al. (2004). The authors reported that "generation-response and concentrations-response relationships were not observed in PFOA". A statistically significant reduction in adult nematodes relative to control was reported at the highest PFOA concentration tested (i.e., 10 nM) during the fourth generation. The PFOA 48-h EC50 for mobility of first generation organisms was reported to be 2.35 mM PFOA. There are questions concerning the study, however, since the authors reported that PFOA was "poorly soluble" in water (although PFOA water solubility exceeds 1 g/L) and 0.5% DMSO was used as a co-solvent to prepare test solutions.

3.1.1.4 Vertebrates

PFOA was not observed to inhibit normal progesterone-induced germinal vesicle breakdown *in vitro* in oocytes of the African clawed frog, *Xenopus laevis*, although it was observed to inhibit normal androstedione-induced germinal vesicle breakdown (Fort et al. 2005). No specific EC50 values for PFOA were reported by the authors.

Fish 96-h LC50 (lethal concentration producing 50% mortality) values ranged from 280 to 2470 mg/L. Although most data are for the fathead minnow, data for bluegill and pumpkinseed sunfish and rainbow trout do not suggest any remarkable differences in species sensitivity to PFOA (see Appendix C). Based on these values, U.S. EPA would classify PFOA as being of low concern for acute aquatic toxicity to fish (Smrchek *et al.* 1995).

3.1.2 Chronic Toxicity

The available chronic aquatic toxicity data (see Appendix D) include 14 day algal EC50 values of 43 and 73 mg/L (in addition to NOECs from the 96-hour studies), 35 day EC10, EC50, and NOEC values of $\geq$ 5.7-8.4, $\geq$ 31.8-35.8 and $\geq$23.9 mg/L, respectively, from aquatic plant microcosm studies, 21-day daphnid reproduction NOECs ranging from 20 – 22 mg/L, 35-day mixed zooplankton community LOECs from freshwater microcosm studies ranging from 10 – 70 mg/L, and chronic fish NOEC values ranging from 0.3 mg/L for steroid hormone levels in male fish from 39 day microcosm studies to 40 mg/L based on survival, length, and weight from an 85-day rainbow trout early life stage study.

In a long-term study, rainbow trout fry were initiated to aflatoxin B1 and then exposed to PFOA at a concentration of 1800 mg/L in the diet (Tilton et al. 2005). At the end of 30 weeks of dosing, enhanced liver tumor incidence and multiplicity were observed in the fish. The authors reported that carcinogenesis appeared independent of peroxisome proliferation because of the lack of induction of peroxisomal *b*-oxidation and catalase. Plasma vitellogenin was elevated in the trout and the authors hypothesized that the data suggested the possibility of an alternative mechanism for tumor enhancement by PFOA in an organism that is relatively resistant to peroxisomal proliferation. However, this study is unlikely to be environmentally relevant given the high exposure concentration of PFOA used in the diet.

Based on these values, U.S. EPA would classify PFOA as being of low concern for chronic aquatic toxicity to algae and low to medium concern for chronic aquatic toxicity to invertebrates and fish (Smrchek *et al.* 1995).

3.1.3 Environmental Toxicity Uncertainty

A variety of different test substances with varying designations and lot numbers were tested in the reported studies. The ammonium salt was generally tested but the exact composition and identification of impurities, which may affect toxicity, was generally not reported. Purity of the test substance was not sufficiently characterized in some of the tests. In some tests, only nominal test chemical concentrations were used to determine test endpoints (although PFOA is stable in water). Tests may or may not have been conducted according to regulatory guidelines and Good Laboratory Practices (GLP) and a variety of testing laboratories conducted the PFOA toxicity studies over a period of time from approximately 1974-2004.

The acute and chronic studies performed by CIT (2003a,b,c; 2004a,b) were conducted following OECD and/or U.S. EPA test guidelines under GLP. These studies utilized a single, well-characterized batch of PFOA for aquatic acute base set testing as well as a chronic reproduction study with *Daphnia magna* and an early-life stage study with the rainbow trout, *Oncorhynchus mykiss*. In addition, although the acute trout and daphnid studies were conducted using nominal concentrations, the algal study and the chronic daphnid and trout studies were conducted with analytical confirmation of test substance concentrations. These studies, in conjunction with other recent studies reporting endpoints based on measured test concentrations (MacDonald *et al.* 2004, DuPont 1999, Oakes *et al.* 2004, Sanderson *et al.* 2003, 2004, Hanson et al. 2005) represent the most reliable evaluations of the acute and chronic aquatic hazard of PFOA to algae, invertebrates and fish.

No data were available to assess the aquatic toxicity of PFOA to marine algal, invertebrate or fish species. Except for a single study with the nematode, *Caenorhabditis elegans*, there were also no PFOA toxicity test data available for terrestrial plant, wildlife, or avian species.

Considering that PFOA from ECF processes are a mix of linear and branched isomers, there is a need to learn if the isomers have differences in acute or chronic toxicity.

3.2 Environmental Toxicity Conclusion

Based on the Environment Canada criteria for Inherent Toxicity (T_i), which indicate that a substance is inherently toxic if its acute toxicity is < 1 mg/L or its chronic toxicity is < 0.1 mg/L, PFOA is not inherently toxic.

The available acute and chronic aquatic toxicity data for PFOA also indicate that it is of low to medium concern for toxicity (i.e., hazard) to freshwater algae, invertebrates, and fish based on data from laboratory studies and the ranking scheme used by U.S. EPA. However, no data were available to assess the aquatic toxicity of PFOA to marine algal, invertebrate or fish species. There were also no PFOA toxicity test data available for either terrestrial plant and wildlife or avian species.

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3.4 Environmental Toxicity:

Appendix A-D

Appendix A. Acute Toxicity of PFOA to Bacteria and Freshwater Algae.

Test Length	Effect Concentration mg/L *	Organism	Comments	Reference
7 min	EC50 > 1000	Sludge	PFOA, ammonium salt (purity >96.5%); FC-143, Lot No. 37	3M Company 1980a; U.S. EPA AR226-0505
30 min 3 h	EC50 > 1000 EC50 > 1000	Sludge	PFOA, ammonium salt (purity > 78%); FC-126, Lot No. 390	3M Company 1987a U.S. EPA AR226-0510
30 min 3 h	EC50 > 1000 EC50 > 1000	Sludge	PFOA, ammonium salt (purity < 45%) in 50% water; FX-1003, Lot No. 2327	3M Company 1990a; U.S. EPA AR226-0514
30 min 3 h	EC50 > 3320 EC50 > 3320	Sludge	PFOA, ammonium salt (20% FC-143) in 80% water; FC-1015-X, Lot No. HOGE 205	3M Company 1996a; U.S. EPA AR226-0524
30 min	EC20 = 420 EC50 = 870	*Photobacterium phosphoreum*	PFOA, ammonium salt (purity > 78%); FC-126, Lot No. 390	3M Company 1987b; U.S. EPA AR226-0511
30 min	EC50 > 1000	*Photobacterium phosphoreum*	PFOA, ammonium salt (purity < 45%) in 50% water; FX-1003, Lot No. 2327	3M Company 1990b; U.S. EPA AR226-0515
30 min	EC50=730	*Photobacterium phosporeum*	PFOA, ammonium salt (purity > 96.5%); FC-143, Lot No. 427	3M Company 1996b; U.S. EPA AR226-0521
30 min	EC50 = 3150	*Photobacterium phosphoreum*	PFOA, ammonium salt (20% FC-143) in 80% water; FC-118	3M Company 1996c; U.S. EPA AR226-0522
30 min	EC50 = 1950	*Photobacterium phosphoreum*	PFOA, ammonium salt (20% FC-143) in 80% water; FC-1015-X, Lot No. HOGE 205	3M Company 1996d; U.S. EPA AR226-0523

* based on nominal test substance concentrations unless indicated otherwise

Appendix A. Acute Toxicity of PFOA to Bacteria and Freshwater Algae (continued)

Test Length	Effect Concentration mg/L *	Organism	Comments	Reference
96 h	EC50, cell count = 49 EC50, dry wt = 149	*Pseudokirchneriella subcapitata*	PFOA, ammonium salt (purity > 96.5%) ; FC-143, Lot No. 37	3M Company 1981; U.S. EPA AR226-0506
72 h 96 h	EC50, cell count = 180 EC50, growth rate = 180 EC50, cell count = 180 EC50 growth rate = 180	*Pseudokirchneriella subcapitata*	PFOA (purity > 96.5%); FC-26, Lot No. 269; (TR Wilbury Sample No. N2803-3)	T.R. Wilbury 1996a; U.S. EPA AR226-0518
96 h	EC50, cell count = 1980 EC50, growth rate = > 3330 NOEC, cell count = 210 NOEC, growth rate = 430	*Pseudokirchneriella subcapitata*	PFOA, ammonium salt (20% FC-143) in 80% water; FC-1015-X, Lot No. HOGE 205	T.R. Wilbury 1996b; U.S. EPA AR226-0526
96 h	** EC50, biomass > 400 ** EC50, growth rate > 400 ** NOEC, biomass = 12.5 ** NOEC, growth rate = 12.5	*Pseudokirchneriella subcapitata*	PFOA, ammonium salt (19.6%) in water, batch #10004	CIT 2004a
168 h	EC50 growth = 2400 "safe level" = 720	Diatoms	PFOA, ammonium salt (unknown purity)	DuPont 1966

* based on nominal test substance concentrations unless indicated otherwise

** based on measured PFOA concentrations

Appendix B. Acute toxicity of PFOA to invertebrates.

Test Length	Effect Concentration, mg/L *	Organism	Comments	Reference
Not reported	EC50 = 183 (424 μM)	*Paramecium caudatum*	PFOA, ammonium salt (purity > 98%)	Matsubara et al. 2006
48 h	EC50 = 1013 (2.35 mM)	*Caenorhabditis elegans*	PFOA	Tominaga et al. 2004
Not reported	Not reported	*Mytilis californianus*	PFOA	Stevenson et al. 2005
48 h	EC50 = 126 EC50 > 1000	*Daphnia magna*	PFOA, ammonium salt (purity > 96.5%); FC-143, Lot No. 37	3M Company 1982 U.S. EPA AR226-0507
48 h	EC50 = 221	*Daphnia magna*	PFOA, ammonium salt (purity > 78%); FC-126, Lot No. 390	3M Company 1987c U.S. EPA AR226-0512
48 h	EC50 = 584	*Daphnia magna*	PFOA, ammonium salt (purity < 45%) in 50% water; FX-1003, Lot No. 2327	EnviroSystems, Inc. 1990a U.S. EPA AR226-0517
48 h	EC50 = 1200 NOEC = 730	*Daphnia magna*	PFOA, ammonium salt (20% FC-143) in 80% water; FC-1015-X, Lot No. HOGE 205	T.R. Wilbury 1996c
48 h	EC50 = 720 NOEC = 360	*Daphnia magna*	PFOA (purity > 96.5%); FC-26, Lot No. 269; (TR Wilbury Sample No. N2803-3)	T.R. Wilbury 1996d
48 h	** EC50 = 480	*Daphnia magna*	PFOA, ammonium salt (19.6%) in water, batch #10004	CIT 2003a
48 h	LC50 = 820	Snails	PFOA, ammonium salt (unknown purity)	DuPont 1966
10 d	** NOEC > 100	*Chironomus tentans*	PFOA (purity > 97%)	MacDonald *et al*. 2004

* based on nominal test substance concentrations unless indicated otherwise
** based on measured PFOA concentrations

Appendix C. Acute Toxicity of PFOA to Vertebrates.

Test Length	Effect Concentration, mg/L *	Organism	Comments	Reference
Not reported	Not reported	*Xenopus laevis*	PFOA	Fort et al. 2005
48 h	LC50 = 1550	Pumpkinseed sunfish *Lepomis gibbosus*	PFOA, ammonium salt (unknown purity)	DuPont 1966
96 h	LC50 = 440	Fathead minnow *Pimephales promelas*	PFOA (purity > 96.5%); FC-26, Lot No. 269	3M Company 1974 U.S. EPA AR226-0498
96 h	LC50 > 420	Bluegill sunfish *Lepomis macrochirus*	PFOA, ammonium salt (purity > 96.5%); FC-143, Lot No. 83	3M Company 1978a U.S. EPA AR226-0499
96 h	LC50 = 569	Bluegill sunfish *Lepomis macrochirus*	PFOA, ammonium salt (purity	3M Company 1978b U.S. EPA AR226-0500
96h	LC50 = 766	Fathead minnow *Pimephales promelas*	PFOA, ammonium salt (purity > 96.5%); FC-143, Lot No. 37	3M Company 1980b U.S. EPA AR226-0504
96h	LC50 = 843	Fathead minnow *Pimephales promelas*	PFOA (purity > 95%); FX-1001	3M Company 1985 U.S. EPA AR226-0509
96h	LC50 = 301	Fathead minnow *Pimephales promelas*	PFOA, ammonium salt (purity > 78%); FC-126, Lot No. 390	3M Company 1987d U.S. EPA AR226-0513
96h	LC50 > 1000	Fathead minnow *Pimephales promelas*	PFOA, ammonium salt (purity < 45%) in 50% water; FX-1003, Lot No. 2327	EnviroSystems, Inc., 1990b U.S. EPA AR226-0516
96 h	LC50 = 280	Fathead minnow *Pimephales promelas*	PFOA (purity > 96.5%); FC-26, Lot No. 269; (TR Wilbury Sample No. N2803-3)	T.R. Wilbury 1996e U.S. EPA AR226-0519
96h	LC50 = 2470	Fathead minnow *Pimephales promelas*	PFOA, ammonium salt (20% FC-143) in 80% water; FC-1015, Lot No. HOGE 205	T.R. Wilbury 1996f U.S. EPA AR226-0525
96 h	LC50 = 634	Bluegill sunfish *Lepomis macrochirus*	PFOA, ammonium salt (purity > 99%)	DuPont 1994
96 h	** LC50 = 800	Rainbow trout *Oncorhynchus mykiss*	FC-118, 20% PFOA solution	DuPont 1999
96 h	** LC50 = 707 ** NOEC = 125	Rainbow trout *Oncorhynchus mykiss*	PFOA, ammonium salt (19.6%) in water, batch #10004	CIT 2003b

* based on nominal test substance concentrations unless indicated otherwise
** based on measured PFOA concentrations

Appendix D. Chronic Toxicity of PFOA to Aquatic Organisms

Test Length	Effect Concentration, mg/L *	Organism	Comment	Reference
14 d	EC50, cell count = 43 EC50, dry wt = 73	*Pseudokirchneriella subcapitata*	PFOA, ammonium salt (purity > 96.5%); FC-143, Lot No. 37	3M Company 1981 U.S. EPA AR226-0506
21 d	NOEC, survival, reprod. = 22 EC50, reprod. = 43	*Daphnia magna*	PFOA ammonium salt (purity > 96.5%); FC-143, Lot No. 264	3M Company 1984 U.S. EPA AR226-0508
21 d	** NOEC = 20	*Daphnia magna*	PFOA, ammonium salt (19.6%) in water, batch #10004	CIT 2003c
35 d	** LOEC = 10 – 70	Mixed zooplankton – indoor microcosm	PFOA, sodium salt, 18.7% in water	Sanderson *et al*. 2003
35 d	** LOEC = 30 – 70	Mixed zooplankton – outdoor microcosm	PFOA, sodium salt, 18.7% in water	Sanderson *et al*. 2004
35 d	EC10 ≥ 5.7, EC50 ≥ 31.8 NOEC 23.9 EC10 ≥ 8.4, EC50 ≥ 35.8 NOEC 23.9	*Myriophyllum spicatum* outdoor microcosm *Myriophyllum sibiricum* outdoor microcosm	PFOA, sodium salt, 18.7% in water	Hanson, et al. 2005
30 d	NOEC, hatchability, survival, growth, histopathology > 100	Fathead minnow *Pimephales promelas*	PFOA, ammonium salt (purity > 96.5%); FC-143, Lot No. 83	EG & G Bionomics 1978a,b U.S. EPA AR226-0501
39 day	** NOEC, survival > 100 ** NOEC, time to first oviposition = 50 ** NOEC, male plasma 11-ketotestosterone, testosterone = 0.3	Fathead minnow *Pimephales promelas* outdoor microcosm	PFOA, 19.4% in water	Oakes *et al*. 2004
85 d	** NOEC = 40	Rainbow trout *Oncorhynchus mykiss*	PFOA, ammonium salt (19.6%) in water, batch #10004	CIT 2004b
30 weeks	Liver tumor incidence 1800 (exposure conc.)	Rainbow trout *Oncorhynchus mykiss*	PFOA	Tilton et al. 2005

* based on nominal test substance concentrations unless indicated otherwise

** based on measured PFOA concentrations

4.0 Environmental Concentrations

4.1 Measured Levels of PFOA in Environmental Samples

This section presents the levels of PFOA as found in environmental samples, as reported in the literature through 1/15/2006. For the purpose of comparison, all reported measurements were standardized to parts per billion (i.e., ng/mL, ng/g).

A summary table of these studies is included in Appendices A & B to this section.

In keeping with the focus on ecological endpoints, data were collected for abiotic and biotic environmental media and not for the indoor or uniquely human environments. As a result drinking water, breast milk, human serum, indoor air, indoor dust, food, and consumer products were beyond the scope of the data collection effort. Also note that the data were collected solely for perfluorooctanoate (PFOA) and not for other compounds.

Recent advances in laboratory methodologies coupled to highly sensitive instrumentation are providing improved capabilities with increased sensitivity and significantly reduced limits of detection for PFOA. These advances make it possible to routinely detect and quantify PFOA in low concentrations (see table below) across a variety of environmental matrices.

These new methods provide critical capabilities that are enabling scientists to determine at unprecedented levels:

- The concentrations of compounds that occur in the environment,
- The mechanisms by which these compounds enter the environment (source pathways), and
- The processes that affect the transport, persistence, and fate of the compounds in the environment.

Before the widespread use of LC/MS/MS capabilities, the ability to detect PFOA was substantially hindered and sample contamination (primarily due to PTFE seals) was a common source of error.

PFOA constitutes a small fraction of the total perfluorinated compound (PFC) burden found in the environment. Where studies were unable to quantify environmental PFOA levels, improved analytical sensitivity has resulted in greater detection frequencies - albeit at lower concentrations. A table of the detection limits from more recent studies is as follows:

Sample Type	Detection Limit	Detection Frequency	Study Citation
Outdoor Air	0.4 pg/m^3	20/20	Harada *et al.* 2005
Soil	0.2 ng/g ww	11/22	DuPont 2003c
Ground Water	0.010 ng/mL	85/87	DuPont 2003c
Fresh Water	0.00006 ng/mL	11/11	Kallenborn *et al.* 2004
Salt Water	0.0052 ng/mL	20/20	Yamashita *et al.* 2004a
Fish Liver	1 ng/g ww	4/44	Kallenborn *et al.* 2004
Bird Liver (Cormorant)	2.5 ng/g ww	12/12	Corsolini and Kannan 2004
Mammal Liver (Seal)	0.3 ng/g ww	8/8	Kallenborn *et al.* 2004

The only study to examine PFOA levels in environmental samples over time (Holmstrom *et al.* 2005) did not detect PFOA in any of the 146 guillemot egg samples collected from 1968 to 2003 in the Baltic Sea, so no trend could be determined. Over this same period, however, perfluorooctane sulfonate (PFOS) levels increased (1968-1997) and then decreased (1997-2003).

4.1.1 Outdoor Air

Published outdoor air measurements of PFOA are available from Japan and the USA. Japanese samples covered 2 areas, Oyamazaki and Morioka, both in the Kyoto prefecture (reporting limits in the pg/m^3 range) covering the time frame of 4/23/2001 to 7/20/2003. The range of the 20 samples (combined from both cities) was 1.6 pg/m^3 to 920 pg/m^3 with no apparent temporal correlation (Harada *et al.* 2005). The geometric means for each of the two cities studied also varied widely: 2.0 pg/m^3 (Morioka) and 263 pg/m^3 (Oyamazaki).

In the USA, samples were collected at a manufacturing site in West Virginia (Barton *et al.* 2006) over the period 11/2003-1/2004. Of the 28 samples analyzed, 5 (18%) had levels above the quantitation limit (0.07 μg/m^3) with the highest and average results being 0.9 μg/m^3 and 0.45 μg/m^3 respectively.

4.1.2 Soil

Three sets of soil measurements were found in the literature, none were considered to represent ambient conditions.

Two sample sets (22 samples total) were collected near a manufacturing site in West Virginia and the results ranged from below the reporting limit (MDL = 1.70 ng/g dry weight) to 170 ng/g dry weight (DuPont 2003c, 2005). As expected, the concentration profile decreased with increasing bore depth (i.e., $conc_{max}$ at surface) with no sample above the LOQ (LOQ = 2 ng/g) below the water table.

The third set of soil samples was collected in October 2003 (Tomakomai, Japan), two months after 40,000 liters (minimal) of fire fighting foam containing PFOS and a variety of perfluorinated carboxylic acids (unknown concentrations) had been used to put out a refinery fire. The mean (n=2) result was 0.00287 ng/mL [sic] (Yamashita *et al.* 2004b).

4.1.3 Sediment

Measurements of PFOA in sediment samples have been reported for several Nordic countries, and the USA. Of the 5 Nordic counties sampled (Finland, Sweden, Norway, Faroe Islands, Iceland) only 2 samples from Norway (0.278 – 0.312 ng/g) were reported above the LOQ (LOQ = 0.20 ng/g) with 13 (non-Norway) samples being reported less than the LOQ (Kallenborn *et al.* 2004).

In the USA, sediment results do not correlate with manufacturing as observed with other environmental matrices. Two studies have reported sediment values for a variety of urban sites, which appear to indicate that sediment is not a final sink for PFOA.

Comparison of manufacturing cities (Decatur, AL; Mobile, AL; Columbus, GA; Pensacola, FL) to non-manufacturing (Cleveland, OH & Port St. Lucie, FL) (3M 2001),

generated 26 samples. Of the manufacturing related samples (14 total), 8 were below the LOD (LOD = 0.080 ng/g) and 6 were below the LOQ (LOQ = 0.200 ng/g). Of the remaining 2 cities, Port St. Lucie reported samples from 1999 were all below the LOD while 2000 and 2001 samplings reported PFOA concentrations ranging from 0.294 ng/g to 1.750 ng/g dry weight. Samples for Cleveland reported 2 samples below the LOD and 1 sample below the LOQ.

Fifteen sites were sampled around the San Francisco Bay area (2004) with 3 samples reported below the LOQ of 0.011 ng/g with the remainder having a range of 0.136 to 0.625 ng/g. For comparison, two sites in Baltimore, MD were sampled with resultant concentrations of 0.186 and 0.390 ng/g (Higgins *et. al.*, 2005)

A single study was reported (Schrap *et al.* 2004) from the Netherlands in which a range of PFOA for the combination of suspended matter and sediments was reported at < 0.40 ng/g to 24 ng/g.

4.1.4 Sewage Sludge and Effluent

Two studies measuring domestic sludge for PFOA have been reported. The first, generated from a survey of eight wastewater treatment plants (WWTP's) had PFOA concentrations (13 samples) ranging from non-detect (MDL = 1.00 ng/g) to a high of 29.4 ng/g (Higgins *et. al*. 2005).

The second study had the highest reported concentration of PFOA in sewage sludge at 244 ng/g (dry weight) in a sample collected near a manufacturing site in the USA (3M 2001). Comparison with 5 other US cities show 2 cities below the reporting limit (LOQ = 0.20 ng/g) and reported a range of 2.40 to 16.50 ng/g (dry weight). The highest concentration for a non-manufacturing site was in Cleveland with a reported result of 3.1 ng/g dry weight (3M 2001).

Sewage sludge studies from Finland & Norway reported PFOA concentrations ranging from less than LOQ (LOQ = 0.20 ng/g) to a maximum of 0.391 ng/g and 0.779 ng/g (wet weight) for Norway and Finland respectively (Kallenborn *et al.* 2004).

Similar to sewage sludge samples, sewage effluent measurements of PFOA were found to correlate to fluorochemical manufacturing locations. The highest value (as with sludge) was near a manufacturing site in Decatur with 2.42 ng/mL being reported for POTW effluent (3M 2001). Lower levels – ranging from 0.001 to 0.675 ng/mL – were detected elsewhere in the USA, Canada, Taiwan, and Nordic countries with the maximum value being reported in both the USA (Cleveland) and Denmark. All sewage effluent samples tested had detectable levels of PFOA.

4.1.5 Landfill Effluent

The highest reported landfill effluent values were for manufacturing-related landfills and ranged from non-detect (3M 2001) to 3,200 ng/mL (DuPont 2003a).

Comparison of public landfill leachates from cities with fluorochemical manufacturing (Decatur, AL; Mobile, AL; Columbus, GA; Pensacola, FL) to control cities (Port St. Lucie, FL) reported a range from (for control) 0.939 ng/mL to 1.03 ng/mL (Port St. Lucie) and for manufacturing sites ranged from non-detect (Pensacola & Mobile) and non-quantifiable (Columbus) to a maximum of 48.1 ng/mL (Decatur).

Outside the United States, 2 sets of landfill effluent studies have been reported (both from Nordic countries). The range of PFOA concentrations from Espoo, Finland (waste collection for Helsinki, Espoo, Vantaa, and other cities) was 0.300 – 0.399 ng/mL while five sites throughout Norway reported values ranging from ranged 0.091 to 0.516 ng/mL (Kallenborn *et al.* 2004).

4.1.6 Ground Water

Ground water (well) tests are used to monitor PFOA concentrations at a number of manufacturing sites in the USA. Of the almost 800 tests reported, levels of PFOA ranged from not detected to a maximum of 322,000 ng/mL (DuPont. 2003a). Temporal trends (2001 – 2003) for industrial (*i.e.,* Decatur, MN and Cottage Grove, AL) effluent and well water monitoring for PFOA concentration were varied with decreasing trends in effluent PFOA concentration and steady or increasing trends for well water PFOA concentrations being observed. (Santoro 2003).

Previous fire-fighting activities that employed aqueous film-forming foams (AFFF's) containing a variety of perfluorinated compounds, including PFOA, have also been shown to impact ground water sources. Fire-fighting training areas have been sampled in both Nevada (NAS Fallon AFB) and Florida (Tyndall AFB, retired) with measurements ranging from below the reporting limit (which decreased from 36 ng/mL in 1999 to 3.0 ng/mL in 2003) to maximums of 116 ng/mL (Tyndall) and 6,570 ng/mL (NAS Fallon AFB) (Moody and Field 1999; Moody *et al.* 2003). As presented in the case of soil samples, ground water results cannot be considered typical environmental concentrations due to the impacts of manufacturing and fire fighting at these sites.

4.1.7 Fresh Water

PFOA in fresh water samples (e.g., lakes, rivers, and streams) has been measured across a variety of geographic locations in Nordic countries, Germany, Japan, Canada and the USA.

For moving fresh water sources (i.e., streams, rivers) PFOA concentrations vary greatly depending upon site specifications with the highest concentration being observed during April and May of 2003 near Osaka, Japan. Fifty-two sites were sampled in this area with

resultant PFOA concentrations ranging from 0.0045 ng/mL to 67 ng/mL (Saito *et. al*. 2004). The highest concentrations were observed slightly downstream of a waste disposal site and are not considered ambient concentrations.

In North America, the highest stream or river PFOA concentration (11 ng/mL) was observed in the Etobicoke creek after a spill (approx. 22,000 L) of fire retardant foam. However, after a period of 21 days at the same sampling site, the PFOA concentration had dropped to 0.0022 ng/mL (Moody *et al.* 2002).

In addition to the aforementioned incident-related concentrations, fluorochemical manufacturing site samples showed elevated PFOA concentrations for nearby rivers/streams. For instance, of 40 samples tested in November 2000 along the Tennessee River, twenty-two samples (approx 40 miles) upstream of a manufacturing site (located in Decatur, AL) reported PFOA concentration below the reporting limit (MDL = 0.025 ng/mL). Once past the manufacturing site, concentrations steadily increased reaching a maximum (0.598 ng/mL) in the lake formed by Wilson Dam, approx 36 miles downstream (Hansen *et al.* 2002).

River sampling sites located in close proximity to industrial activities in Taiwan (Tseng, *et. al.* 2006) show elevated levels of PFOA. Two rivers, Tour-Chyan and Nan-Kan, in the northern (Taipei) region reported PFOA concentrations of 0.113 ng/mL and 0.181 ng/mL, respectively.

Quiet water sources (i.e., lakes and ponds) exhibited a maximum PFOA concentration of 0.76 ng/mL (reported samples from 1999) being observed in Port St. Lucie, Florida, USA which was not reproducible the following year (0.097 ng/mL, sampling period 2000) (3M 2001). The maximum PFOA concentration for the Great Lakes region was 0.070 ng/mL (Lake Ontario, 2003; Boulanger *et. al*.,2004). In total, 26 samples from the Great Lakes area have been reported with a range of PFOA from < 0.0003 ng/mL (Simcik & Dorweiler, 2005) to 0.070 ng/mL (Boulanger, *et. al.* 2004).

4.1.8 Salt Water

A variety of marine samples (e.g., oceans, seas, and coastal waters) have been analyzed for PFOA. The highest result (obtained from a sample collected off the Koshien Coast (Japan) was reported to be 0.447 ng/mL (Saito, *et al.* 2004). The majority of measurements (47/55, 86%) were below 0.010 ng/mL with the lowest result (0.00002 ng/mL) coming from the open Pacific Ocean (Yamashita *et al.* 2004a). Typical levels near the surface (< 5 m) of the central section of the open oceans reported the overall lowest range of PFOA concentration (0.000015 to 0.000056 ng/mL).

As expected, there is a correlation of coastal manufacturing activity with the observed concentration for near-shore measurements. The highest near-shore (within 50 miles) PFOA concentrations were observed to correlate with large industrial cities, namely: Tokyo Bay, 0.154 – 0.192 ng/mL (Tokyo, Japan), Koshien Coast, 0.447 ng/mL (Kobe, Osaka, Sakai, Japan), and the western coast of Korea, 0.320 ng/mL (Seoul, Korea).

4.1.9 Plants

No studies of PFOA in terrestrial wild plants were identified. Benthic algae from three areas around Lake Michigan were all reported to have PFOA concentrations below the reporting limit of 0.2 ng/g. (Kannan *et al*. 2005).

4.1.10 Invertebrates

Three species of invertebrates were collected in the wild. Amphipods, from three Lake Michigan regions, all exhibited PFOA concentrations below the LOQ (LOQ = 5 ng/g) (Kannan *et al*, 2005). *Mysis* and *Diporeia* samples taken from Lake Ontario (2001) showed a large PFOA variation in reported averages - 2.5 ng/g (*Mysis*) and 90 ng/g (*Diporeia*) (Martin *et al.* 2004a).

4.1.11 Freshwater Fish

Over 380 samples of freshwater fish from Nordic countries, Poland, Czech Republic, Canada and the USA have been analyzed for PFOA. Many of the reported results (> 81%) were below the respective reporting limits of these studies.

Species	Common Name
Notropus cornutus	Common Shiner
Esox lucius	Pike
Salvelinus alpinus	Artic char
Perca fluviatilis	Perch
Lota loat	Burbot
Catostomus commersoni	White Sucker
Salvelinus fontinalis	Brook Trout
Coregonus clupeaformis	Lake Whitefish
Salvelinus namaycush	Lake Trout
Lepomis machrochirus	Bluegill Sunfish
Pimephales promelas	Fathead Minnow
Osmerus mordax	Rainbow Smelt
Cottus cognatus	Slimy Sculpin
Alosa pseudoharengus	Alewife
Cyprinus carpio	Carp
Micropterus salmoides	Largemouth Bass
Neogobius melanostomus	Round Gobies
Micropterus dolomieui	Smallmouth Bass
Carassius gibelio	Giebel Carp
Anguilla anguilla	Eel
Salmo trutta	Brown Trout

Table 1. Listing of Freshwater Species Covered in this Summary Report

The highest detected concentration, (91 ng/g wet weight; Moody *et al.* 2002), was from the liver of a common shiner downstream of a spill of fire retardant foam containing PFOA. PFOA concentrations were predictably distributed geographically along the spill zone ranging from a low of 6 ng/g upstream of the spill to the high previously mentioned.

Of ambient measurements, samples from Lake Ontario (whole body homogenates: Lake Trout; 1.0 ng/g, Sculpin; 44 ng/g, Alewife; 1.6 ng/g, and Smelt; 2 ng/g) and Finland (liver: Pike 0.890 – 1.42 ng/g) reported PFOA concentrations above the LOQ (Martin *et al.* 2004a).

4.1.12 Rain Water

A single rain event in Winnipeg, Manitoba, Canada was captured and analyzed in July 2004 (Loewen et al, 2005). PFOA was not detected above the MDL of 0.0072 ng/mL.

Rain samples were also collected in the Nordic region in the last quarter of 2003. All six samples tested showed PFOA concentrations above the LOQ, ranging from 0.00823 ng/mL (Helsinki) to 0.0168 ng/mL (RaÖ) (Kallenborn, et. al., 2004).

Temporal trends for three USA sites (Maryland, Delaware, New York) show a wide range of PFOA concentrations with a maximum being detected in a 1998 sample from Delaware (0.090 ng/mL) (Scott *et al.* 2003). Several samples from Maryland during the same time frame also exhibited similar spikes with several being in the 0.030 ng/mL – 0.050 ng/mLrange.

4.1.13 Plankton and Shellfish

Concentrations of PFOA in homogenate samples of zooplankton, northern shrimp and blunt gaper clams were reported from the Canadian eastern Arctic in 2002 (clams & zooplankton) and 2000-2001 (shrimp). Zooplankton concentrations (5 samples) ranged from 1.75 ng/g to 3.42 ng/g with an average of 2.58 ng/g. In comparison, only 1 of the 7 shrimp samples (14%) was above the MDL of 0.200 ng/g with a value of 0.520 ng/g. All 5 clam samples collected in the same region as the zooplankton were below the MDL.

Similarly, 77 oysters sampled from the Gulf of Mexico and the Chesapeake Bay, had PFOA levels below the limit of quantification of <19 ng/g (Giesy and Kannan 2001 as summarized in APME 2002). Recent analysis of oysters from Taiwan (Tseng et. al, 2006), showed significantly higher levels of PFOA with concentrations ranging from 130 ng/g (muscle) to 180 ng/g (homogenate).

Crayfish and zebra mussel samples from 3 Lake Michigan regions were reported to have PFOA levels below the MDL of 0.200 ng/g, crayfish and the LOQ of 5 ng/g, zebra mussels (Kannan *et. al.* 2005).

4.1.14 Saltwater Fish

Over 33 species of saltwater fish have been sampled for PFOA and are included in this paper. The geographic distribution of samples is quite diverse and ranges from the Baltic and Mediterranean Seas, North Pacific Ocean, to the coasts of the Canadian Arctic, Belgium, Colombia and Antarctica. Historically, most results were below the limits of quantification. However, recent advances in both instrumental and laboratory methodologies provide a greater ability to quantify PFOA levels in fish samples.

The highest level of PFOA was detected in a liver samples with all other biological matrices (muscle, plasma) reported below the LOQ or MDL. Less than 9 percent of the samples reported were above the LOQ and, of those, the highest concentrations were sampled near Denmark (Herring, 5.4 ng/g wet weight; Kallenborn *et al.* 2004), and the eastern Canadian Arctic (Redfish, 5.3 ng/g wet weight; Tomy *et al.* 2004).

Species	Common Name
Platichthys flesus	Flounder
Zoarces viviparous	Eelpout
Clupea harengus	Herring
Myoxocephalus scorpius	Shorthorn Sculpin
Limanda limanda	Dab
Hippoglossoides platessoides	Long-rough Dab
Gadus morhua	Atlantic Cod
Thunnus thynnus	Bluefin Tuna
Xiphias gladius	Swordfish
Salmo salar	Atlantic Salmon
Myoxocephalus scorpioides	Arctic Sculpin
Sebastes mentella	Deepwater Redfish
Boreogadus saida	Artic Cod
Oncorhynchus tshawytscha	Chinook Salmon
Thunnus albacares	Yellow-fin Tuna
Lateolabrax japonicus	Seabass
Conger myriaster	Conger Eel
Pleuronectiformes pleuronectidae	Flatfish
Sebastiscus marmoratus	Japanese Stingfish
Sebastes inermis	Rockfish
Acanthopgrus schlegeli	Black Seabream
Trachurus japonicus	Japanese Scad
Argyrosomus argentatus	White Croaker
Thamnaconus modestus	Black Scraper
Stephanolepis cirrhifer	Filefish
Konosirus punctatus	Gizzard Shad
Liza haematocheila	Redlip Mullet
Pagrus major	Red Seabream
Acanthopagrus schlegeli	Yellowfin Seabream
Paralichtys olivaceus	Lefteye Flounder
Caranx ignobilis	Giant Trevally
Tropidinius amoenus	Ornate Jobfish
Nematalosa come	Perth Herring

Table 2. Listing of Saltwater Species Covered in this Summary Report

4.1.15 Reptiles

Plasma samples from loggerhead and Kemp's ridley sea turtles along the southeastern coast of the USA were sampled during 2003 and analyzed for PFOA (Keller *et al.* 2004). The mean result for the 73 loggerhead turtles was 3.2 ng/mL and 3.57 ng/mL for the 6 Kemp's ridley turtles. While mean results differed by only 10%, the variability in the range of the 2 species was significantly greater being 0.493 – 8.14 ng/mL and 2.77 – 4.25 ng/mL for loggerhead and Kemp's ridley respectively.

In comparison, snapping turtles (5 samples, plasma) & yellow-blotched map turtles (6 samples, liver)] were sampled in the 1990's (Giesy *et al* 2001) in Michigan and Mississippi (respectively). The PFOA concentration for both sample groups was found to be below the LOQ (LOQ range 2.5 ng/g to 180 ng/g).

Species	Common Name
Lepidochelys kempii	Kemp's ridley sea Turtle
Caretta caretta	Loggerhead Turtle
Chelydra serpentina	Snapping Turtle
Graptemys flavimaculata	Yellow-blotched Map Turtle

Table 3. Listing of Reptiles Species Covered in this Summary Report

4.1.16 Birds

Sample information has been compiled on 32 species of birds (see table 4).

Species	Common Name
Fulmarus glacialis	Fulmar
Uria aalge	Guillemot
Larus crassirostris	Black-tailed Gull
Anas poecilorhyncha	Spot-billed Duck
Larus ridibundus	Black-headed Gull
Milvus lineatus	Black-eared Kite
Ardea cinerea	Gray Heron
Phalacrocorax carbo	Common Cormorant
Cepphus grylle	Black Guillemot
Haliaeetus albicilla	White-Tailed Eagle
Gavia immer	Common Loon
Larus hyperboreus	Glaucous Gulls
Rissa tridactyla	Black legged Kittiwake
Limosa lapponica	Bar-tailed Godwit
Larus canus	Common Gull
Podiceps nigricollis	Black-necked Grebe
Sterna hirundo	Common Tern
Calidris tenuirostris	Great Knot
Tringa nebularia	Greenshank
Larus argentatus	Herring Gull
Crocethia alba	Sanderling
Egretta garzetta	Little Egret
Phalacrocorax auritus	Double-Crested Cormorant
Stercorarius maccormicki	Polar Skua
Larus delawarensis	Ring-billed Gull
Phoebastria nigripes	Black-footed Albatross
Pelecanus occidentalis	Brown Pelican
Haliaeetus leucocephalus	Bald Eagle
Corvus corone	Carrion Corw
Anas platyrhynchos	Mallard Duck
Anas acuta	Pintail Duck
Anas platyrhynchos var. domestica	Domestic Duck

Table 4. Listing of Bird Species Covered in this Summary Report

Of the 32 species of birds (over 1700 samples), the highest concentration of PFOA was reported in cormorant samples taken in 1997 along the Mediterranean (450 ng/g, Kannan *et al.* 2002b) and was likely related to the close proximity of the sampling sites to a fluoro-based manufacturing site. Overall, the highest (100–450 ng/g) concentrations were found in liver samples with the remainder of reports (encompassing a broad set of biological matrices including: eggs, muscle, plasma, ovaries, and testes) all below the LOQ.

It is important to note that the majority of bird samples (> 89%) were below the LOQ of the individual study and the aforementioned value of 450 ng/g sample was treated as an outlier.

4.1.17 Amphibians

Only a single report of amphibian studies was found (Giesy *et al* 2001). Green frog liver was analyzed for PFOA and found to be below the LOQ (2.5 to 180 ng/g).

4.1.18 Mammals

Sampling of mammalian tissue can be classified by type (i.e., terrestrial or marine) and by tissue.

4.1.18.1 Terrestrial Mammals

A study of Black Cattle from Japan (Guruge *et. al*. 2004) reported only 12% (2 of 16) of samples at or above the concentration observed in solvent blanks (0.090 ng/mL). In addition, there was no correlation between PFOA concentration and age of the cattle over the range of 9 – 27 months.

The highest result for liver samples from mink was reported to be 27 ng/g dry weight (sample source Massachusetts; Giesy and Kannan 2001), whereas the average of 31 samples was 8 ng/g. Similar studies from Illinois, South Carolina, and Louisiana (81 samples) reported only 6% of samples above LOQ with a maximum of 24 ng/g. Similar studies for liver samples from river otters (Giesy and Kannan) reported a maximum concentration of 19 ng/g wet weight (LOQ = 35 ng/g).

A manufacturing related study was performed (Hoff *et al.* 2004) in which wood mice were captured in Blokkersdijk (manufacturing site) and Galgenweel (3 km distance) in Belgium. All of the 42 samples (21 from each location) reported PFOA levels below the MDL of 11 ng/g.

4.1.18.2 Marine Mammals

Polar bear samples (liver tissue) have been extensively studied in a variety of locations. A recent circumpolar study (Smithwick *et. al*. 2005a) of liver samples covering 7 sites reported PFOA concentrations ranging from < LOD of 2.3 ng/g to a high of 57.1 ng/g (wet wt.; South Baffin Island) with the majority (> 85%) of the samples having a level of PFOA above the LOD.

Seal samples have been broadly studied across a variety of locations for 7 seal species. Liver tissue samples were the only tissue matrix that were reported to have PFOA concentration(s) above the LOQ. The highest PFOA value for the entire sample population (PFOA concentrations above LOQ) was reported for a harbor seal in Denmark with a value of 5.6 ng/g.

Walrus samples from the Eastern Arctic reported a range of PFOA concentrations ranging from < MDL of 0.2 ng/g wet weight) to a high of 0.69 ng/g. (Tomy *et. al.,* 2003)

Six species of whales have been studied using liver tissue as the primary sampling medium (2 muscle samples also reported, both < LOD). The highest concentration of PFOA in this group was from a Beluga whale sampled in 1996 with a reported concentration of 2.76 ng/g (wet weight) (Tomy et. al., 2004).

Free ranging dolphins present a widely studied group of mammals with tissue samplings from liver, kidney, muscle, and blood. The majority of the samplings were reported below the LOQ. Two study areas have reported concentrations of PFOA > 100 ng/g in blood (Houde *et. al.*, 2005). The first, east of Charleston, South Carolina, had a PFOA range of 4.6 ng/g to 163 ng/g (average of 47 samples equals 44 ng/g). The second area, Delaware Bay, has a reported range of 20 ng/g to 115 ng/g (average for 5 samples equals 72 ng/g). Blood samples taken from the Bermuda region showed significantly smaller concentrations of PFOA, ranging from 0.6 ng/g to 0.9 ng/g.

Two porpoise samples from liver were reported (van De Vijver, 2003) below the MDL of 110 ng/g, wet weight.

4.1.19 Environmental Concentrations Uncertainty

Current analytical methods make it possible to detect PFOA at low concentrations in a variety of environmental matrices. The first reports of PFOA in environmental samples in 1999 have been followed by reports with continuously improving analytical sensitivity, hence the number of non-detects is being replaced by measurable, but small amounts being detected. Although the total number of environmental samples analyzed is growing, there currently is not enough data in any one matrix with significant sample density to clearly define temporal or geographical trends among the various environmental media (including biota). Continuing studies, which incorporate more defined sampling strategies employing currently available analytical technology, should help define temporal / geographic trends. Considering that PFOA from ECF processes are a mix of linear and branched isomers, it is not clear whether or not the isomers would behave differently in regards to where they are found in the environment.

4.2 Environmental Concentrations Conclusion

The data available to date do not seem to indicate that PFOA collects in any environmental media other than the aquatic environment, which appears to be the likely sink.

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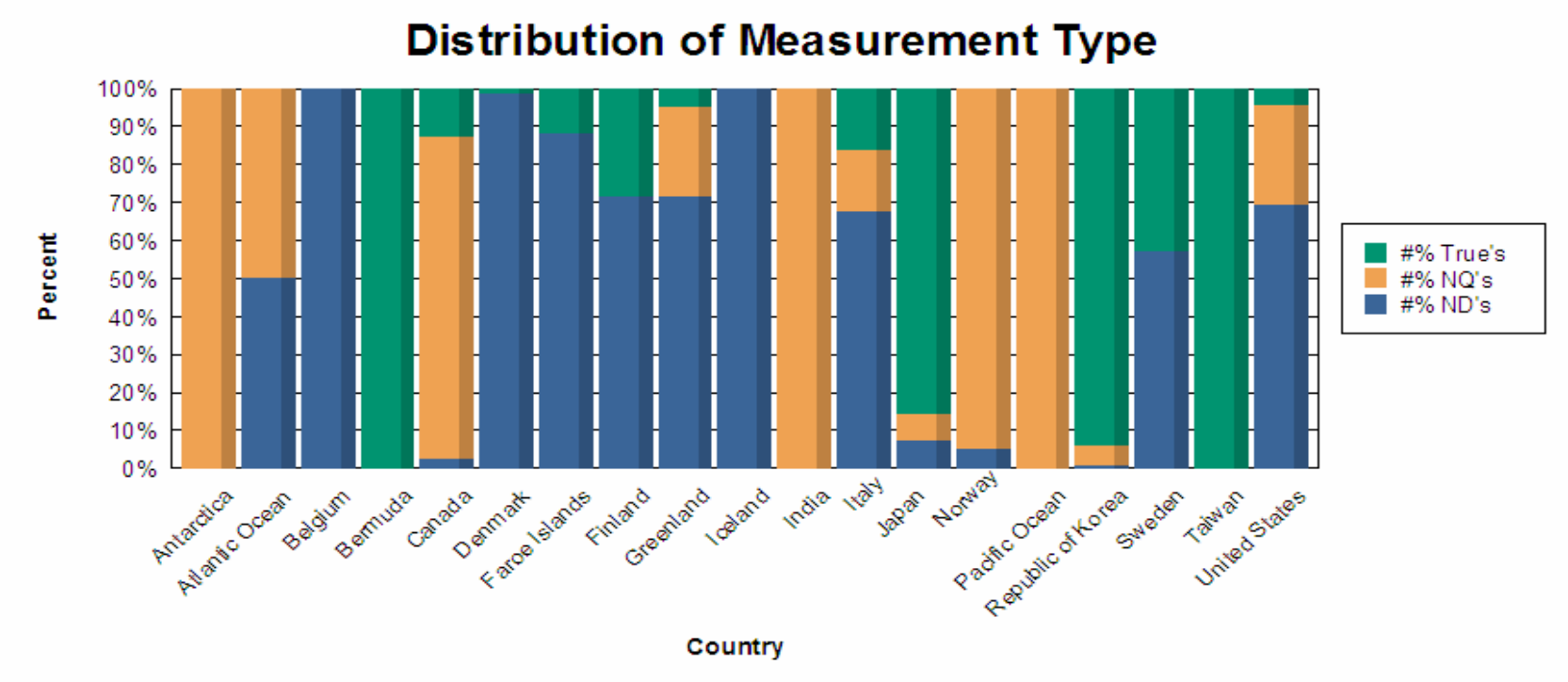
4.4 Environmental Concentrations: Appendix A

Appendix A



				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Amphibian	*Green Frog*	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			4
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			4

All Concentrations reported as ppb and are rounded upward to nearest integer. Values in red indicate Min & Max Conc at reporting limits

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Bird	*Bald Eagle*	**Arch. Environ. Contam. Toxicol. 48, 559-566**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19
			Max Conc																			38
			Min Conc																			19
			Nos ND's																			
			Nos NQ's																			19
		Environ. Sci. Technol. 35(7): 1339-1342	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			45
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45
			Max Conc																			90
			Min Conc																			19
			Nos ND's																			
			Nos NQ's																			64
	Bar-tailed godwit	**Chemosphere 49: 225-231**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
			Max Conc																36			
			Min Conc																36			
			Nos ND's																			
			Nos NQ's																3			
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
			Max Conc																36			
			Min Conc																36			
			Nos ND's																			
			Nos NQ's																3			
	Black Guillemot	**Environ. Pollut. 136(2): 323-329**	Samples	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0
			Max Conc									7										
			Min Conc									7										
			Nos ND's																			
			Nos NQ's									15										
		Environ. Sci. Technol. 38(2): 373-380	Samples	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					2														
			Min Conc					2														
			Nos ND's																			
			Nos NQ's					5														
		Total	Samples	0	0	0	0	5	0	0	0	15	0	0	0	0	0	0	0	0	0	0
			Max Conc					2				7										
			Min Conc					2				7										
			Nos ND's																			
			Nos NQ's					5				15										

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Bird	*Black legged kittiwake*	**Environ. Sci. Technol. 38(24): 6475-6481**	Samples	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					0														
			Min Conc					0														
			Nos ND's					4														
			Nos NQ's																			
		Total	Samples	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					0														
			Min Conc					0														
			Nos ND's					4														
			Nos NQ's																			
	Black-eared Kite	**Chemosphere 49: 225-231**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
			Max Conc													21						
			Min Conc													19						
			Nos ND's																			
			Nos NQ's													1						
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
			Max Conc													21						
			Min Conc													19						
			Nos ND's																			
			Nos NQ's													1						
	Black-footed Albatross	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			22
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			22
	Black-headed Gull	**Chemosphere 49: 225-231**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	5	0	0	0
			Max Conc													21			36			
			Min Conc													21			36			
			Nos ND's																5			
			Nos NQ's													1						
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	5	0	0	0
			Max Conc													21			36			
			Min Conc													21			36			
			Nos ND's																5			
			Nos NQ's													1						

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Bird	*Black-necked grebe*	**Chemosphere 49: 225-231**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
			Max Conc																36			
			Min Conc																36			
			Nos ND's																2			
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
			Max Conc																36			
			Min Conc																36			
			Nos ND's																2			
			Nos NQ's																			
	Black-tailed Gull	**Chemosphere 49: 225-231**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0	9	0	0	0
			Max Conc													19			36			
			Min Conc													16			36			
			Nos ND's													14			9			
			Nos NQ's													8						
		Environ. Sci. Technol. 35(7): 1339-1342	Samples	0	0	0	0	0	0	0	0	0	0	0	0	24	0	0	15	0	0	0
			Max Conc													90			90			
			Min Conc													90			90			
			Nos ND's													14			9			
			Nos NQ's													32			15			
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	46	0	0	24	0	0	0
			Max Conc													90			90			
			Min Conc													16			36			
			Nos ND's													28			18			
			Nos NQ's													40			15			
	Brown Pelican	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			2
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			2
	Common Cormorant	**Chemosphere 49: 225-231**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0
			Max Conc													19						
			Min Conc													19						
			Nos ND's																			
			Nos NQ's													10						

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Bird	*Common Cormorant*	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0
			Max Conc												90							
			Min Conc												90							
			Nos ND's																			
			Nos NQ's												12							
		Organohalogen Compounds 66: 4079-4085	Samples	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0
			Max Conc												450							
			Min Conc												29							
			Nos ND's																			
			Nos NQ's												12							
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	24	10	0	0	0	0	0	0
			Max Conc												450	19						
			Min Conc												29	19						
			Nos ND's																			
			Nos NQ's												24	10						
	Common gull	**Chemosphere 49: 225-231**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
			Max Conc																36			
			Min Conc																36			
			Nos ND's																			
			Nos NQ's																3			
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
			Max Conc																36			
			Min Conc																36			
			Nos ND's																			
			Nos NQ's																3			
	Common Loon	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			8
		Environ. Sci. Technol. 38(2): 373-380	Samples	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					2														
			Min Conc					2														
			Nos ND's																			
			Nos NQ's					5														
		Total	Samples	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	8
			Max Conc					2														90
			Min Conc					2														90
			Nos ND's																			
			Nos NQ's					5														8

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Bird	*Common tern*	**Chemosphere 49: 225-231**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
			Max Conc																36			
			Min Conc																36			
			Nos ND's																1			
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
			Max Conc																36			
			Min Conc																36			
			Nos ND's																1			
			Nos NQ's																			
	Double-Crested Cormorant	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	9
			Max Conc					90														90
			Min Conc					90														90
			Nos ND's																			
			Nos NQ's					4														9
		Total	Samples	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	9
			Max Conc					90														90
			Min Conc					90														90
			Nos ND's																			
			Nos NQ's					4														9
	Fulmar	**Environ. Pollut. 136(2): 323-329**	Samples	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc							7												
			Min Conc							7												
			Nos ND's							18												
			Nos NQ's																			
		Environ. Sci. Technol. 38(2): 373-380	Samples	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					2														
			Min Conc					2														
			Nos ND's																			
			Nos NQ's					5														
		Nordic Council of Ministers, Tromso, Norway	Samples	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc							1												
			Min Conc							1												
			Nos ND's							20												
			Nos NQ's																			
		Total	Samples	0	0	0	0	5	0	20	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					2		7												
			Min Conc					2		1												
			Nos ND's							38												
			Nos NQ's					5														

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Bird	*Glaucous gulls*	**Environ. Sci. Technol. 39(19): 7439-7445**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0
			Max Conc														1					
			Min Conc														1					
			Nos ND's														30					
			Nos NQ's																			
		Environ. Sci. Technol. 38(24): 6475-6481	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					4														
			Min Conc					0														
			Nos ND's					0														
			Nos NQ's					3														
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0
			Max Conc					4									1					
			Min Conc					0									1					
			Nos ND's					0									30					
			Nos NQ's					3														
	Gray Heron	**Chemosphere 49: 225-231**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
			Max Conc													19						
			Min Conc													19						
			Nos ND's																			
			Nos NQ's													2						
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
			Max Conc													19						
			Min Conc													19						
			Nos ND's																			
			Nos NQ's													2						
	Great knot	**Chemosphere 49: 225-231**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
			Max Conc																36			
			Min Conc																36			
			Nos ND's																1			
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
			Max Conc																36			
			Min Conc																36			
			Nos ND's																1			
			Nos NQ's																			
	Greenshank	**Chemosphere 49: 225-231**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
			Max Conc																36			
			Min Conc																36			
			Nos ND's																3			
			Nos NQ's																			

Appendix A

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Bird	*Greenshank*	Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
			Max Conc																36			
			Min Conc																36			
			Nos ND's																3			
			Nos NQ's																			
	Guillemot		Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0
			Max Conc																	2		
			Min Conc																	2		
			Nos ND's																	18		
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0
			Max Conc																	2		
			Min Conc																	2		
			Nos ND's																	18		
			Nos NQ's																			
	Herring Gull	**Chemosphere 49: 225-231**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0
			Max Conc																36			
			Min Conc																36			
			Nos ND's																10			
			Nos NQ's																			
		Environ. Sci. Technol. 35(7): 1339-1342	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			4
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	4
			Max Conc																36			90
			Min Conc																36			90
			Nos ND's																10			
			Nos NQ's																			4
	Little egret	**Chemosphere 49: 225-231**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
			Max Conc																36			
			Min Conc																36			
			Nos ND's																4			
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
			Max Conc																36			
			Min Conc																36			
			Nos ND's																4			
			Nos NQ's																			

Appendix A

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Bird	*Polar Skua*	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc	90																		
			Min Conc	90																		
			Nos ND's																			
			Nos NQ's	2																		
		Total	Samples	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc	90																		
			Min Conc	90																		
			Nos ND's																			
			Nos NQ's	2																		
	Ring-billed Gull	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			3
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			3
	Sanderling	**Chemosphere 49: 225-231**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
			Max Conc																36			
			Min Conc																36			
			Nos ND's																2			
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
			Max Conc																36			
			Min Conc																36			
			Nos ND's																2			
			Nos NQ's																			
	Spot-billed Duck	**Chemosphere 49: 225-231**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
			Max Conc													19						
			Min Conc													16						
			Nos ND's													1						
			Nos NQ's													1						
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
			Max Conc													19						
			Min Conc													16						
			Nos ND's													1						
			Nos NQ's													1						

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Fish	*Alewife*	**Environ. Sci. Technol. 38(20): 5379-5385**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Max Conc																			2
			Min Conc																			2
			Nos ND's																			
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Max Conc																			2
			Min Conc																			2
			Nos ND's																			
			Nos NQ's																			
	Arctic Sculpin	**Environ. Sci. Technol. 38(2): 373-380**	Samples	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					2														
			Min Conc					2														
			Nos ND's																			
			Nos NQ's					1														
		Nordic Council of Ministers, Tromso, Norway	Samples	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc							1												
			Min Conc							1												
			Nos ND's							2												
			Nos NQ's																			
		Total	Samples	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					2		1												
			Min Conc					2		1												
			Nos ND's							2												
			Nos NQ's					1														
	Artic char	**Nordic Council of Ministers, Tromso, Norway**	Samples	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc							1												
			Min Conc							1												
			Nos ND's							3												
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc							1												
			Min Conc							1												
			Nos ND's							3												
			Nos NQ's																			
	Artic Cod	**Environ. Sci. Technol. 38(24): 6475-6481**	Samples	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0
			Max Conc									0										
			Min Conc									0										
			Nos ND's									5										
			Nos NQ's																			

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Fish	*Artic Cod*	Total	Samples	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0
			Max Conc									0										
			Min Conc									0										
			Nos ND's									5										
			Nos NQ's																			
	Atlantic Cod	**Nordic Council of Ministers, Tromso, Norway**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0
			Max Conc																	1		
			Min Conc																	1		
			Nos ND's																	16		
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0
			Max Conc																	1		
			Min Conc																	1		
			Nos ND's																	16		
			Nos NQ's																			
	Bluefin Tuna	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc		90																	
			Min Conc		90																	
			Nos ND's																			
			Nos NQ's		8																	
		Organohalogen Compounds 66: 4079-4085	Samples	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0
			Max Conc												72							
			Min Conc												3							
			Nos ND's																			
			Nos NQ's												14							
		Total	Samples	0	8	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0
			Max Conc		90										72							
			Min Conc		90										3							
			Nos ND's																			
			Nos NQ's		8										14							
	Brook Trout	**Environ. Sci. Technol. 38(2): 373-380**	Samples	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					2														
			Min Conc					2														
			Nos ND's																			
			Nos NQ's					2														
		Organohalogen Compounds 66: 4069-4073	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23
			Max Conc																			72
			Min Conc																			72
			Nos ND's																			23
			Nos NQ's																			

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Fish	*Brook Trout*	Total	Samples	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	23
			Max Conc					2														72
			Min Conc					2														72
			Nos ND's																			23
			Nos NQ's					2														
	Brown Trout	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			23
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			23
	Burbot	**Nordic Council of Ministers, Tromso, Norway**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
			Max Conc														1					
			Min Conc														1					
			Nos ND's														1					
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
			Max Conc														1					
			Min Conc														1					
			Nos ND's														1					
			Nos NQ's																			
	Carp	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			10
		Organohalogen Compounds 66: 4069-4073	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
			Max Conc																			72
			Min Conc																			72
			Nos ND's																			10
			Nos NQ's																			10
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20
			Max Conc																			90
			Min Conc																			72
			Nos ND's																			10
			Nos NQ's																			20

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Fish	*Chinook Salmon*	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			12
		Organohalogen Compounds 66: 4069-4073	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
			Max Conc																			72
			Min Conc																			72
			Nos ND's																			12
			Nos NQ's																			12
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24
			Max Conc																			90
			Min Conc																			72
			Nos ND's																			12
			Nos NQ's																			24
	Dab	**Nordic Council of Ministers, Tromso, Norway**	Samples	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc							1												
			Min Conc							1												
			Nos ND's							3												
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc							1												
			Min Conc							1												
			Nos ND's							3												
			Nos NQ's																			
	Deepwater Redfish	**Environ. Sci. Technol. 38(24): 6475-6481**	Samples	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0
			Max Conc									5										
			Min Conc									0										
			Nos ND's									5										
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0
			Max Conc									5										
			Min Conc									0										
			Nos ND's									5										
			Nos NQ's																			
	Eelpout	**Nordic Council of Ministers, Tromso, Norway**	Samples	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc						1													
			Min Conc						1													
			Nos ND's																			
			Nos NQ's																			

Appendix A

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Fish	*Eelpout*	Total	Samples	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc						1													
			Min Conc						1													
			Nos ND's																			
			Nos NQ's																			
	Flounder	**Nordic Council of Ministers, Tromso, Norway**	Samples	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc						1													
			Min Conc						1													
			Nos ND's						4													
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc						1													
			Min Conc						1													
			Nos ND's						4													
			Nos NQ's																			
	Herring	**Nordic Council of Ministers, Tromso, Norway**	Samples	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc						5													
			Min Conc						5													
			Nos ND's																			
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc						5													
			Min Conc						5													
			Nos ND's																			
			Nos NQ's																			
	Japanese Seaperch	**J. Chromatogr. A 1105(2006) 119-126**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
			Max Conc																		340	
			Min Conc																		340	
			Nos ND's																			
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
			Max Conc																		340	
			Min Conc																		340	
			Nos ND's																			
			Nos NQ's																			
	Lake Trout	**Environ. Sci. Technol. 38(20): 5379-5385**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Max Conc																			1
			Min Conc																			1
			Nos ND's																			
			Nos NQ's																			

Appendix A

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Fish	*Lake Trout*	**Environ. Sci. Technol. 38(2): 373-380**	Samples	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					2														
			Min Conc					2														
			Nos ND's																			
			Nos NQ's					1														
		Nordic Council of Ministers, Tromso, Norway	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
			Max Conc														1					
			Min Conc														1					
			Nos ND's														1					
			Nos NQ's																			
		Total	Samples	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1
			Max Conc					2									1					1
			Min Conc					2									1					1
			Nos ND's														1					
			Nos NQ's					1														
	Lake Whitefish	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			12
		Environ. Sci. Technol. 38(2): 373-380	Samples	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					2														
			Min Conc					2														
			Nos ND's																			
			Nos NQ's					2														
		Organohalogen Compounds 66: 4069-4073	Samples	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					72														
			Min Conc					72														
			Nos ND's					12														
			Nos NQ's					2														
		Total	Samples	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	12
			Max Conc					72														90
			Min Conc					2														90
			Nos ND's					12														
			Nos NQ's					4														12

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Fish	*Long-rough dab*	**Nordic Council of Ministers, Tromso, Norway**	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	0	0	0	0	0	5 1 1 5	0	0	0	0	0	0	0	0	0
		Total	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	0	0	0	0	0	5 1 1 5	0	0	0	0	0	0	0	0	0
	Perch	**Nordic Council of Ministers, Tromso, Norway**	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	0	0	0	0	0	0	0	0	0	1 1 1 1	0	0	4 1 1 4	0	0
		Total	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	0	0	0	0	0	0	0	0	0	1 1 1 1	0	0	4 1 1 4	0	0
	Pike	**Environ. Sci. Technol. 38(2): 373-380**	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	1 2 2 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Nordic Council of Ministers, Tromso, Norway	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	0	0	0	7 1 1 5	0	0	0	0	0	1 1 1 1	0	0	0	0	0
		Total	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	1 2 2 1	0	0	7 1 1 5	0	0	0	0	0	1 1 1 1	0	0	0	0	0
	Rainbow Smelt	**Environ. Sci. Technol. 38(20): 5379-5385**	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1 2 2

Appendix A

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Fish	*Rainbow Smelt*	Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Max Conc																			2
			Min Conc																			2
			Nos ND's																			
			Nos NQ's																			
	Round Gobies	**Arch. Environ. Contam. Toxicol. 48, 559-566**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
			Max Conc																			0
			Min Conc																			0
			Nos ND's																			
			Nos NQ's																			12
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
			Max Conc																			0
			Min Conc																			0
			Nos ND's																			
			Nos NQ's																			12
	Seabass	**J. Chromatogr. A 1105(2006) 119-126**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
			Max Conc																		340	
			Min Conc																		340	
			Nos ND's																			
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
			Max Conc																		340	
			Min Conc																		340	
			Nos ND's																			
			Nos NQ's																			
	Shorthorn Sculpin	**Environ. Pollut. 136(2): 323-329**	Samples	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0
			Max Conc									7										
			Min Conc									7										
			Nos ND's									15										
			Nos NQ's																			
		Nordic Council of Ministers, Tromso, Norway	Samples	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
			Max Conc										1									
			Min Conc										1									
			Nos ND's										1									
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	0	0	0	15	1	0	0	0	0	0	0	0	0	0
			Max Conc									7	1									
			Min Conc									7	1									
			Nos ND's									15	1									
			Nos NQ's																			

Appendix A

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Fish	*Slimy Sculpin*	**Environ. Sci. Technol. 38(20): 5379-5385**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Max Conc																			44
			Min Conc																			44
			Nos ND's																			
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Max Conc																			44
			Min Conc																			44
			Nos ND's																			
			Nos NQ's																			
	Smallmouth Bass	**Arch. Environ. Contam. Toxicol. 48, 559-566**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
			Max Conc																			2
			Min Conc																			0
			Nos ND's																			
			Nos NQ's																			14
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
			Max Conc																			2
			Min Conc																			0
			Nos ND's																			
			Nos NQ's																			14
	Swordfish	**Organohalogen Compounds 66: 4079-4085**	Samples	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0
			Max Conc												36							
			Min Conc												3							
			Nos ND's																			
			Nos NQ's												12							
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0
			Max Conc												36							
			Min Conc												3							
			Nos ND's																			
			Nos NQ's												12							
	Tilapia	**J. Chromatogr. A 1105(2006) 119-126**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0
			Max Conc																		120	
			Min Conc																		100	
			Nos ND's																			
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0
			Max Conc																		120	
			Min Conc																		100	
			Nos ND's																			
			Nos NQ's																			

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Fish	*White Sucker*	**Environ. Sci. Technol. 38(2): 373-380**	Samples	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					1														
			Min Conc					1														
			Nos ND's																			
			Nos NQ's																			
		Total	Samples	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					1														
			Min Conc					1														
			Nos ND's																			
			Nos NQ's																			
	Yellow-fin Tuna	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0
			Max Conc															90				
			Min Conc															90				
			Nos ND's																			
			Nos NQ's															12				
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0
			Max Conc															90				
			Min Conc															90				
			Nos ND's																			
			Nos NQ's															12				
Invertebrate	*Amphipods*	**Arch. Environ. Contam. Toxicol. 48, 559-566**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
			Max Conc																			5
			Min Conc																			5
			Nos ND's																			
			Nos NQ's																			3
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
			Max Conc																			5
			Min Conc																			5
			Nos ND's																			
			Nos NQ's																			3
	Blunt Gaper Clam	**Environ. Sci. Technol. 38(24): 6475-6481**	Samples	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					0														
			Min Conc					0														
			Nos ND's					2														
			Nos NQ's																			
		Total	Samples	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					0														
			Min Conc					0														
			Nos ND's					2														
			Nos NQ's																			

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Invertebrate	*Crayfish*	**Arch. Environ. Contam. Toxicol. 48, 559-566**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
			Max Conc																			0
			Min Conc																			0
			Nos ND's																			
			Nos NQ's																			3
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
			Max Conc																			0
			Min Conc																			0
			Nos ND's																			
			Nos NQ's																			3
	Diporeia	**Environ. Sci. Technol. 38(20): 5379-5385**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			
	Greenland Smoothcockle clam	**Environ. Sci. Technol. 38(24): 6475-6481**	Samples	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					0														
			Min Conc					0														
			Nos ND's					3														
			Nos NQ's																			
		Total	Samples	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					0														
			Min Conc					0														
			Nos ND's					3														
			Nos NQ's																			
	Mysis	**Environ. Sci. Technol. 38(20): 5379-5385**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Max Conc																			3
			Min Conc																			3
			Nos ND's																			
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Max Conc																			3
			Min Conc																			3
			Nos ND's																			
			Nos NQ's																			

Appendix A

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Invertebrate	*Northern Shrimp*	**Environ. Sci. Technol. 38(24): 6475-6481**	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	0	0	0	0	7 1 0 5	0	0	0	0	0	0	0	0	0	0
		Total	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	0	0	0	0	7 1 0 5	0	0	0	0	0	0	0	0	0	0
	Oyster	**J. Chromatogr. A 1105(2006) 119-126**	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12 180 130	0
		Total	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12 180 130	0
	Zebra mussel	**Arch. Environ. Contam. Toxicol. 48, 559-566**	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6 5 5 6
		Total	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6 5 5 6
Mammal	*Arctic Fox*	**Environ. Sci. Technol. 38(2): 373-380**	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	10 2 2 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Total	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	10 2 2 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix A

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Mammal	*Beluga Whale*	**Environ. Sci. Technol. 38(24): 6475-6481**	Samples	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					3														
			Min Conc					1														
			Nos ND's																			
			Nos NQ's																			
		Total	Samples	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					3														
			Min Conc					1														
			Nos ND's																			
			Nos NQ's																			
	Bottlenose Dolphin	**Environ. Sci. Technol. 36(12): 2566-2571**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
			Max Conc													3						
			Min Conc													3						
			Nos ND's																			
			Nos NQ's																			
		Environ. Sci. Technol. 39(17): 6591-6598	Samples	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	107
			Max Conc				1															72
			Min Conc				1															6
			Nos ND's																			
			Nos NQ's																			
		Environ. Sci. Technol. 35(7): 1339-1342	Samples	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc		90																	
			Min Conc		90																	
			Nos ND's																			
			Nos NQ's		5																	
		Organohalogen Compounds 66: 4079-4085	Samples	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0
			Max Conc												72							
			Min Conc												3							
			Nos ND's																			
			Nos NQ's												6							
		Total	Samples	0	5	0	2	0	0	0	0	0	0	0	10	1	0	0	0	0	0	107
			Max Conc		90		1								72	3						72
			Min Conc		90		1								3	3						6
			Nos ND's																			
			Nos NQ's		5										6							

Appendix A

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Mammal	*California Sea Lion*	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0
			Max Conc															90				
			Min Conc															90				
			Nos ND's																			
			Nos NQ's															6				
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0
			Max Conc															90				
			Min Conc															90				
			Nos ND's																			
			Nos NQ's															6				
	Common Dolphin	**Organohalogen Compounds 66: 4079-4085**	Samples	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
			Max Conc												38							
			Min Conc												38							
			Nos ND's																			
			Nos NQ's												2							
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
			Max Conc												38							
			Min Conc												38							
			Nos ND's																			
			Nos NQ's												2							
	Elephant Seal	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0
			Max Conc															90				
			Min Conc															90				
			Nos ND's																			
			Nos NQ's															5				
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0
			Max Conc															90				
			Min Conc															90				
			Nos ND's																			
			Nos NQ's															5				
	Fin Whale	**Organohalogen Compounds 66: 4079-4085**	Samples	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
			Max Conc												38							
			Min Conc												38							
			Nos ND's																			
			Nos NQ's												1							
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
			Max Conc												38							
			Min Conc												38							
			Nos ND's																			
			Nos NQ's												1							

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Mammal	*Ganges River Dolphin*	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
			Max Conc											90								
			Min Conc											90								
			Nos ND's																			
			Nos NQ's											2								
		Total	Samples	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
			Max Conc											90								
			Min Conc											90								
			Nos ND's																			
			Nos NQ's											2								
	Gray Seal	**Environ. Sci. Technol. 37(24): 5545-5550**	Samples	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc		110																	
			Min Conc		110																	
			Nos ND's																			
			Nos NQ's		12																	
		Environ. Sci. Technol. 35(7): 1339-1342	Samples	0	0	0	0	12	0	0	0	0	0	0	26	0	0	0	0	0	0	0
			Max Conc					90							90							
			Min Conc					90							90							
			Nos ND's																			
			Nos NQ's					12							26							
		Nordic Council of Ministers, Tromso, Norway	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
			Max Conc																	2		
			Min Conc																	1		
			Nos ND's																			
			Nos NQ's																			
		Total	Samples	0	12	0	0	12	0	0	0	0	0	0	26	0	0	0	0	3	0	0
			Max Conc		110			90							90					2		
			Min Conc		110			90							90					1		
			Nos ND's																			
			Nos NQ's		12			12							26							
	Harbor Porpoise	**Environ. Sci. Technol. 37(24): 5545-5550**	Samples	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc		110																	
			Min Conc		110																	
			Nos ND's																			
			Nos NQ's		2																	
		Total	Samples	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc		110																	
			Min Conc		110																	
			Nos ND's																			
			Nos NQ's		2																	

Appendix A

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Mammal	*Harbor Seal*	**Environ. Sci. Technol. 39(18): 6978-6984**	Samples	0	0	0	0	0	82	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc						1													
			Min Conc						1													
			Nos ND's						82													
			Nos NQ's																			
		Environ. Sci. Technol. 35(7): 1339-1342	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
			Max Conc															90				
			Min Conc															90				
			Nos ND's																			
			Nos NQ's															3				
		Nordic Council of Ministers, Tromso, Norway	Samples	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc						6													
			Min Conc						0													
			Nos ND's						82													
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	87	0	0	0	0	0	0	0	0	3	0	0	0	0
			Max Conc						6									90				
			Min Conc						0									90				
			Nos ND's						164													
			Nos NQ's															3				
	Hooded Seal	**Environ. Sci. Technol. 37(24): 5545-5550**	Samples	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc		110																	
			Min Conc		110																	
			Nos ND's		2																	
			Nos NQ's																			
		Total	Samples	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc		110																	
			Min Conc		110																	
			Nos ND's		2																	
			Nos NQ's																			
	Human		Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	356
			Max Conc																			6
			Min Conc																			2
			Nos ND's																			
			Nos NQ's																			

Appendix A

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Mammal	*Human*	**Chemosphere 54: 1599-1611**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	238
			Max Conc																			0
			Min Conc																			0
			Nos ND's																			
			Nos NQ's																			
		Environ. Sci. Technol. 37(21): 888-891	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62
			Max Conc																			47
			Min Conc																			8
			Nos ND's																			
			Nos NQ's																			60
		J. Occup. Health. 46: 141-147	Samples	0	0	0	0	0	0	0	0	0	0	0	0	360	0	0	0	0	0	0
			Max Conc													12						
			Min Conc													0						
			Nos ND's																			
			Nos NQ's																			
		Organohalogen Compounds 66: 4079-4085	Samples	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0
			Max Conc												3							
			Min Conc												3							
			Nos ND's												50							
			Nos NQ's																			
		Organohalogen Compounds 66: 4041-4045	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,200	0	0	0
			Max Conc																88			
			Min Conc																15			
			Nos ND's																925			
			Nos NQ's																			
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	50	360	0	0	1,200	0	0	656
			Max Conc												3	12			88			47
			Min Conc												3	0			15			0
			Nos ND's												50				925			
			Nos NQ's																			60
	Japanese Black Cattle	**Organohalogen Compounds 66: 4029-4034**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0
			Max Conc													0						
			Min Conc													0						
			Nos ND's													3						
			Nos NQ's																			

Appendix A

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Mammal	*Japanese Black Cattle*	Total	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	0	0	0	0	0	0	0	0	15 0 0 3	0	0	0	0	0	0
	Long Finned Pilot Whale	**Environ. Pollut. 136(2): 323-329**	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	0	0	30 7 7 30	0	0	0	0	0	0	0	0	0	0	0	0
		Nordic Council of Ministers, Tromso, Norway	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	0	0	4 2 0 30	0	0	0	0	0	0	0	0	0	0	0	0
		Organohalogen Compounds 66: 4079-4085	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	0	0	0	0	0	0	0	2 38 38 2	0	0	0	0	0	0	0
		Total	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	0	0	34 7 0 60	0	0	0	0	2 38 38 2	0	0	0	0	0	0	0
	Mink	**Environ. Sci. Technol. 36(12): 2566-2571**	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	112 20 4 16
		Environ. Sci. Technol. 35(7): 1339-1342	Samples Max Conc Min Conc Nos ND's Nos NQ's	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18 90 90 16 18

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Mammal	*Mink*	**Environ. Sci. Technol. 38(2): 373-380**	Samples	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					2														
			Min Conc					2														
			Nos ND's																			
			Nos NQ's					1														
		Total	Samples	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	130
			Max Conc					2														90
			Min Conc					2														4
			Nos ND's																			32
			Nos NQ's					1														18
	Minke whale	**Environ. Pollut. 136(2): 323-329**	Samples	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
			Max Conc									7										
			Min Conc									7										
			Nos ND's									5										
			Nos NQ's																			
		Environ. Sci. Technol. 37(24): 5545-5550	Samples	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc		110																	
			Min Conc		110																	
			Nos ND's		1																	
			Nos NQ's																			
		Nordic Council of Ministers, Tromso, Norway	Samples	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0
			Max Conc										1									
			Min Conc										1									
			Nos ND's										5									
			Nos NQ's																			
		Total	Samples	0	1	0	0	0	0	0	0	5	5	0	0	0	0	0	0	0	0	0
			Max Conc		110							7	1									
			Min Conc		110							7	1									
			Nos ND's		1							5	5									
			Nos NQ's																			
	Narwhal	**Environ. Sci. Technol. 38(24): 6475-6481**	Samples	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					1														
			Min Conc					1														
			Nos ND's																			
			Nos NQ's																			
		Total	Samples	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					1														
			Min Conc					1														
			Nos ND's																			
			Nos NQ's																			

Appendix A

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Mammal	*Northern Fur Seal*	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0
			Max Conc															90				
			Min Conc															90				
			Nos ND's																			
			Nos NQ's															14				
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0
			Max Conc															90				
			Min Conc															90				
			Nos ND's																			
			Nos NQ's															14				
	Polar Bear	**Environ. Pollut. 136(2): 323-329**	Samples	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0
			Max Conc									12										
			Min Conc									12										
			Nos ND's																			
			Nos NQ's									10										
		Environ. Sci. Technol. 35(7): 1339-1342	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			17
		Environ. Sci. Technol. 38(2): 373-380	Samples	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					9														
			Min Conc					9														
			Nos ND's																			
			Nos NQ's																			
		Environ. Toxicol. Chem. 24(4): 981-986	Samples	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
			Max Conc									10										
			Min Conc									10										
			Nos ND's																			
			Nos NQ's									10										
		Total	Samples	0	0	0	0	7	0	0	0	11	0	0	0	0	0	0	0	0	0	17
			Max Conc					9				12										90
			Min Conc					9				10										90
			Nos ND's																			
			Nos NQ's									20										17

Appendix A

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Mammal	*Ringed Seal*	**Environ. Pollut. 136(2): 323-329**	Samples	0	0	0	0	0	0	0	0	35	0	0	0	0	0	0	0	0	0	0
			Max Conc									12										
			Min Conc									7										
			Nos ND's									30										
			Nos NQ's									5										
		Environ. Sci. Technol. 39(19): 7416-7422	Samples	0	0	0	0	0	0	0	0	75	0	0	0	0	0	0	0	0	0	0
			Max Conc									1										
			Min Conc									1										
			Nos ND's									105										
			Nos NQ's									5										
		Environ. Sci. Technol. 35(7): 1339-1342	Samples	0	0	0	0	24	0	0	0	0	0	0	18	0	18	0	0	0	0	0
			Max Conc					90							90		90					
			Min Conc					90							90		90					
			Nos ND's																			
			Nos NQ's					24							18		18					
		Environ. Sci. Technol. 38(2): 373-380	Samples	0	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					2														
			Min Conc					2														
			Nos ND's																			
			Nos NQ's					33														
		Total	Samples	0	0	0	0	43	0	0	0	110	0	0	18	0	18	0	0	0	0	0
			Max Conc					90				12			90		90					
			Min Conc					2				1			90		90					
			Nos ND's									135										
			Nos NQ's					57				10			18		18					
	River Otter	**Environ. Sci. Technol. 36(12): 2566-2571**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
			Max Conc																			13
			Min Conc																			8
			Nos ND's																			
			Nos NQ's																			12
		Environ. Sci. Technol. 35(7): 1339-1342	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			17

Appendix A

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Mammal	*River Otter*	Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19
			Max Conc																			90
			Min Conc																			8
			Nos ND's																			
			Nos NQ's																			29
	Sea Otter	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0
			Max Conc															90				
			Min Conc															90				
			Nos ND's																			
			Nos NQ's															8				
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0
			Max Conc															90				
			Min Conc															90				
			Nos ND's																			
			Nos NQ's															8				
	Sperm Whale	**Environ. Sci. Technol. 37(24): 5545-5550**	Samples	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc		110																	
			Min Conc		110																	
			Nos ND's																			
			Nos NQ's		1																	
		Total	Samples	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc		110																	
			Min Conc		110																	
			Nos ND's																			
			Nos NQ's		1																	
	Striped Dolphin	**Environ. Sci. Technol. 37(24): 5545-5550**	Samples	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc		110																	
			Min Conc		110																	
			Nos ND's																			
			Nos NQ's		4																	
		Environ. Sci. Technol. 35(7): 1339-1342	Samples	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc		90																	
			Min Conc		90																	
			Nos ND's		4																	
			Nos NQ's		4																	
		Organohalogen Compounds 66: 4079-4085	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc												4							
			Min Conc												72							
			Nos ND's												72							
			Nos NQ's												4							

Appendix A

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Mammal	*Striped Dolphin*	Total	Samples	0	8	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
			Max Conc		110										72							
			Min Conc		90										72							
			Nos ND's		8																	
			Nos NQ's		4										4							
	Walrus	**Environ. Sci. Technol. 38(24): 6475-6481**	Samples	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					1														
			Min Conc					0														
			Nos ND's					1														
			Nos NQ's																			
		Total	Samples	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					1														
			Min Conc					0														
			Nos ND's					1														
			Nos NQ's																			
	Weddell Seal	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc	90																		
			Min Conc	90																		
			Nos ND's																			
			Nos NQ's	1																		
		Total	Samples	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc	90																		
			Min Conc	90																		
			Nos ND's																			
			Nos NQ's	1																		
	White-beaked dolphin	**Environ. Sci. Technol. 37(24): 5545-5550**	Samples	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc		110																	
			Min Conc		110																	
			Nos ND's		20																	
			Nos NQ's																			
		Total	Samples	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc		110																	
			Min Conc		110																	
			Nos ND's		20																	
			Nos NQ's																			
	White-sided dolphin	**Environ. Sci. Technol. 37(24): 5545-5550**	Samples	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc		110																	
			Min Conc		110																	
			Nos ND's		4																	
			Nos NQ's																			

Appendix A

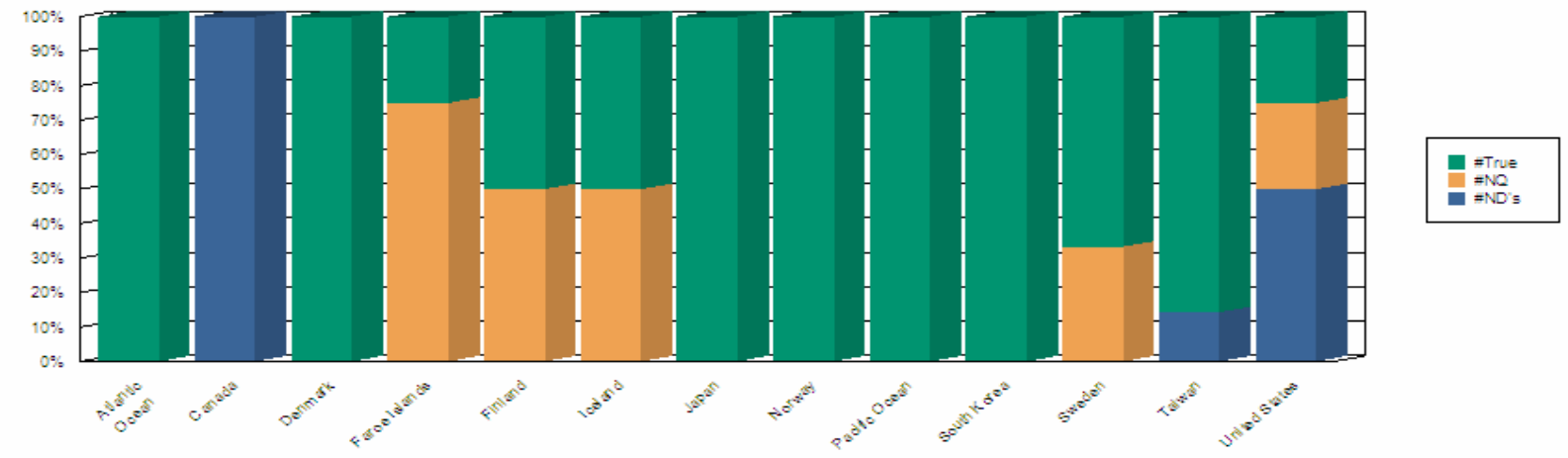
				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Mammal	*White-sided dolphin*	Total	Samples	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc		110																	
			Min Conc		110																	
			Nos ND's		4																	
			Nos NQ's																			
	Wood Mice	**Environ. Health Perspect. 112(6): 681-686**	Samples	0	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc			110																
			Min Conc			110																
			Nos ND's			21																
			Nos NQ's																			
		Total	Samples	0	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc			110																
			Min Conc			110																
			Nos ND's			21																
			Nos NQ's																			
Plankton	*Zooplankton*	**Environ. Sci. Technol. 38(24): 6475-6481**	Samples	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					3														
			Min Conc					2														
			Nos ND's																			
			Nos NQ's																			
		Total	Samples	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Max Conc					3														
			Min Conc					2														
			Nos ND's																			
			Nos NQ's																			
Plant	*Benthic algae*	**Arch. Environ. Contam. Toxicol. 48, 559-566**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
			Max Conc																			0
			Min Conc																			0
			Nos ND's																			
			Nos NQ's																			3
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
			Max Conc																			0
			Min Conc																			0
			Nos ND's																			
			Nos NQ's																			3
Reptile	*Loggerhead Turtle*	**Environ. Sci. Technol. 39(23): 9101-9108**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	79
			Max Conc																			4
			Min Conc																			3
			Nos ND's																			
			Nos NQ's																			

Appendix A

				Antarctica	Atlantic Ocean	Belgium	Bermuda	Canada	Denmark	Faroe Islands	Finland	Greenland	Iceland	India	Italy	Japan	Norway	Pacific Ocean	Republic of Korea	Sweden	Taiwan	United States
Reptile	*Loggerhead Turtle*	Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	79
			Max Conc																			4
			Min Conc																			3
			Nos ND's																			
			Nos NQ's																			
	Snapping Turtle	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			5
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			5
	Yellow-blotched Map Turtle	**Environ. Sci. Technol. 35(7): 1339-1342**	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			6
		Total	Samples	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
			Max Conc																			90
			Min Conc																			90
			Nos ND's																			
			Nos NQ's																			6

Appendix B

Distribution of Measurement Type



				Atlantic Ocean	Canada	Denmark	Faroe Islands	Finland	Iceland	Japan	Norway	Pacific Ocean	South Korea	Sweden	Taiwan	United States
Air	**Air**	Bull. Environ. Contam Toxicol 74:64-69	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**28** **0.0000** **0.0009**	**0**	**0**	**0**	**0**	**0**	**0**
		Total	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	0	0	0	0	0	28 **0.0000** **0.0009**	0	0	0	0	0	0
Fresh Water	**Effluent**	J. Chromatogr. A 1105(2006) 119-126	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4** **0.0008** **0.1700** **1**	**0**
		Total	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	0	0	0	0	0	0	0	0	0	0	4 **0.0008** **0.1700** **1**	0

Ambient Results only. All Concentrations reported as ppb and are rounded upward if necessary. Values in red indicate Min & Max Conc at reporting limits

				Atlantic Ocean	Canada	Denmark	Faroe Islands	Finland	Iceland	Japan	Norway	Pacific Ocean	South Korea	Sweden	Taiwan	United States
Fresh Water	Lake	Environ. Sci. Technol. 39(22): 8678-8683	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**11** **0.0001** **0.0194** **3**
		Environ. Sci. Technol. 38(15): 4064-4070	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**16** **0.0150** **0.0700** **3**
		Nordic Council of Ministers, Tromso, Norway	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**5** **0.0048** **0.0082**	**0**	**0**	**0**	**0**	**0**
		Society of Environmental Toxicology and Chemistry North America Annual	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**8** **0.0023** **0.0110** **7** **3**
		Total	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	0	0	0	0	0	0	5 **0.0048** **0.0082**	0	0	0	0	35 **0.0001** **0.0700** **7** **9**
	Landfill Effluent	Nordic Council of Ministers, Tromso, Norway	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**3** **0.3000** **0.3990**	**0**	**0**	**6** **0.0913** **0.5160**	**0**	**0**	**0**	**0**	**0**
		Total	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	0	0	0	3 **0.3000** **0.3990**	0	0	6 **0.0913** **0.5160**	0	0	0	0	0
	Pond	J. Occup. Health. 46: 49-59	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**1** **0.0038** **0.0038**	**0**	**0**	**0**	**0**	**0**	**0**
		U.S. Environmental Protection Agency Administrative Record 226-0670	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2** **0.0250** **0.0250** **2**

				Atlantic Ocean	Canada	Denmark	Faroe Islands	Finland	Iceland	Japan	Norway	Pacific Ocean	South Korea	Sweden	Taiwan	United States
Fresh Water	**Pond**	U.S. Environmental Protection Agency Administrative Record 226-0672	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2** **0.0573** **0.0631** **2**
		U.S. Environmental Protection Agency Administrative Record 226-0673	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2** **0.0249** **0.0270** **3**
		Total	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	0	0	0	0	0	1 **0.0038** **0.0038**	0	0	0	0	0	6 **0.0249** **0.0631** **7**
	Rain	Environ. Sci. Technol. 39(9): 2944-2951	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**3** **0.0072** **0.0072** **3**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
		Total	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	3 **0.0072** **0.0072** **3**	0	0	0	0	0	0	0	0	0	0	0
	Rain Water	Nordic Council of Ministers, Tromso, Norway	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**2** **0.0082** **0.0131**	**0**	**0**	**0**	**0**	**0**	**4** **0.0107** **0.0168**	**0**	**0**
		Total	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	0	0	0	2 **0.0082** **0.0131**	0	0	0	0	0	4 **0.0107** **0.0168**	0	0
	River	Arch. Environ. Contam. Toxicol. 48, 559-566	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4** **0.0044** **0.0147**
		Environ. Sci. Technol. 39(15): 5524-5530	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3** **0.0087** **0.0087**

				Atlantic Ocean	Canada	Denmark	Faroe Islands	Finland	Iceland	Japan	Norway	Pacific Ocean	South Korea	Sweden	Taiwan	United States
Fresh Water	**River**	Environ. Sci. Technol. 39(22): 8678-8683	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1** **0.0012** **0.0012**
		Environ. Sci. Technol. 36(8): 1681-1685	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**18** **0.0250** **0.0250** **18**
		J. Chromatogr. A 1105(2006) 119-126	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**6** **0.1130** **0.1810**	**0**
		J. Occup. Health. 46: 49-59	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**129** **0.0001** **19.4000**	**0**	**0**	**0**	**0**	**0**	**0**
		Organohalogen Compounds 66: 4069-4073	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**24** **0.0056** **0.0216** **18**
		U.S. Environmental Protection Agency Administrative Record 226-0670	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**6** **0.0236** **0.0267** **18**
		U.S. Environmental Protection Agency Administrative Record 226-0672	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**6** **0.0092** **0.0250** **24**
		U.S. Environmental Protection Agency Administrative Record 226-0673	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**6** **0.0255** **0.0828** **24**
		Total	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	0	0	0	0	0	129 **0.0001** **19.4000**	0	0	0	0	6 **0.1130** **0.1810**	68 **0.0012** **0.0828** **102**

				Atlantic Ocean	Canada	Denmark	Faroe Islands	Finland	Iceland	Japan	Norway	Pacific Ocean	South Korea	Sweden	Taiwan	United States
Fresh Water	**Sewage Effluent**	Nordic Council of Ministers, Tromso, Norway	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**1** **0.0013** **0.0013**	**5** **0.0199** **0.0228**	**0**	**0**	**3** **0.0202** **0.0225**	**0**	**0**	**0**	**0**	**0**
		Total	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	0	0	1 **0.0013** **0.0013**	5 **0.0199** **0.0228**	0	0	3 **0.0202** **0.0225**	0	0	0	0	0
	Tap Water	J. Occup. Health. 46: 49-59	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**7** **0.0001** **0.0400**	**0**	**0**	**0**	**0**	**0**	**0**
		Total	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	0	0	0	0	0	7 **0.0001** **0.0400**	0	0	0	0	0	0
	Wastewater Effluent	Environ. Sci. Technol. 39(15): 5524-5530	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3** **0.0220** **0.0220**
		Total	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	0	0	0	0	0	0	0	0	0	0	0	3 **0.0220** **0.0220**
	Wastewater Influent	Environ. Sci. Technol. 39(15): 5524-5530	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3** **0.0040** **0.0040** **3**
		Total	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	0	0	0	0	0	0	0	0	0	0	0	3 **0.0040** **0.0040** **3**
Salt Water	**Bay**	Environ. Sci. Technol. 38(21): 5522-5528	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**3** **0.1543** **0.1920**	**0**	**0**	**0**	**0**	**0**	**0**

				Atlantic Ocean	Canada	Denmark	Faroe Islands	Finland	Iceland	Japan	Norway	Pacific Ocean	South Korea	Sweden	Taiwan	United States
Salt Water	Bay	J. Chromatogr. A 1105(2006) 119-126	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2** **0.1300** **0.2700**	**0**
		J. Occup. Health. 46: 49-59	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**3** **0.0021** **0.0322**	**0**	**0**	**0**	**0**	**0**	**0**
		Nordic Council of Ministers, Tromso, Norway	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**4** **0.0035** **0.0040**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
		Total	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	0	0	0	0	4 **0.0035** **0.0040**	6 **0.0021** **0.1920**	0	0	0	0	2 **0.1300** **0.2700**	0
	Ocean	Environ Sci Technol 38(15): 4056-4063	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**11** **0.0002** **0.3200**	**0**	**0**	**0**
		Environ. Sci. Technol. 38(21): 5522-5528	Nos Min Conc Max Conc Nos ND's Nos NQ's	**3** **0.0001** **0.0002**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**7** **0.0000** **0.0001**	**0**	**0**	**0**	**0**
		J. Occup. Health. 46: 49-59	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**0**	**0**	**0**	**2** **0.0115** **0.4477**	**0**	**0**	**0**	**0**	**0**	**0**
		Nordic Council of Ministers, Tromso, Norway	Nos Min Conc Max Conc Nos ND's Nos NQ's	**0**	**0**	**0**	**3** **0.0036** **0.0072**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
		Total	Nos Min Conc Max Conc Nos ND's Nos NQ's	3 **0.0001** **0.0002**	0	0	3 **0.0036** **0.0072**	0	0	2 **0.0115** **0.4477**	0	7 **0.0000** **0.0001**	11 **0.0002** **0.3200**	0	0	0

				Atlantic Ocean	Canada	Denmark	Faroe Islands	Finland	Iceland	Japan	Norway	Pacific Ocean	South Korea	Sweden	Taiwan	United States
Solids	Sewage Sludge	Environ. Sci. Technol. 38(21): 5522-5528	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	0	0	0	7 0.2000 0.7070 2	0	2 0.0002 0.0004	2 0.3770 0.3910	5 0.0001 0.0005	0	6 0.2000 0.7790 1	0	0
		J. Occup. Health. 46: 49-59	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	0	0	0	7 0.2000 0.7070 2	0	1 0.0019 0.0019	2 0.3770 0.3910	0	0	6 0.2000 0.7790 1	0	0
		Nordic Council of Ministers, Tromso, Norway	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	0	4 0.0062 0.0085	0	6 0.0940 0.7070	0	0	0	0	0	0	0	0
		Total	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	0	4 0.0062 0.0085	0	6 0.0940 0.7070	0	3 0.0002 0.0019	0	5 0.0001 0.0005	0	0	0	0
3/10/200	Sediment	Environ. Sci. Technol. 39(11): 3946-3956	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	0	0	0	0	0	0	0	0	0	0	0	51 0.0110 0.6250 6 3
		Nordic Council of Ministers, Tromso, Norway	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	0	0	3 0.2000 0.2000 3	7 0.2000 0.2000 7	4 0.2000 0.2000 4	0	2 0.2780 0.3120	0	0	3 0.2000 0.2000 3	0	0
		Total	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	0	0	3 0.2000 0.2000 3	7 0.2000 0.2000 7	4 0.2000 0.2000 4	0	2 0.2780 0.3120	0	0	3 0.2000 0.2000 3	0	51 0.0110 0.6250 6 3
Solids	Sewage	Nordic Council of Ministers, Tromso, Norway	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	0	3 0.3060 0.6750	1 1.0750 1.0750	0	4 0.2000 0.2980 2	0	0	0	0	0	0	0
		Total	Nos Min Conc Max Conc Nos ND's Nos NQ's	0	0	3 0.3060 0.6750	1 1.0750 1.0750	0	4 0.2000 0.2980 2	0	0	0	0	0	0	0

5.0 Analytical: Approaches and Challenges In Environmental Matrices

5.1 Analytical Determinations of Perfluorooctanoic Acid

5.1.1 From Total Fluorine to Low-Level Speciation

In 1954 Wickbold commented that the difficulty in determining fluorine in organic substances is primarily in the data interpretation since very energetic agents must be used to destroy the carbon fluorine bond (Wickbold 1954). His development of the oxy-hydrogen torch combustion system allowed the determination of fluorine-containing compounds, in some cases, to levels as low as the 20-mg/kg level. In this method, however, only total fluorine is determined and no speciation is possible.

In 1968, Taves determined the level of fluorine in human blood serum by comparing the levels in ashed and unashed samples to demonstrate that there were two forms of fluorine in blood, "exchangeable and non-exchangeable" (Taves 1968). The latter, he suggested, might be organically-bound fluorine. In 1980 Belisle and Hagen developed a gas chromatographic method to determine perfluorooctanoic acid (PFOA) in blood and other biological samples (Belisle *et al.* 1980). Their method required the use of diazomethane to form the methyl ester of PFOA. The method was able to measure PFOA levels as low as 15 ug/L.

Introduction of liquid chromatography tandem mass spectrometry (LC/MS/MS) in the 1990s made possible the determination of PFOA in various matrices without derivitization. As reported by Martin *et al.* after a 2003 PFOA workshop, there are still many analytical chemistry challenges to obtaining scientifically defensible data due to a variety of matrix and analytical methodology considerations (Martin *et al.* 2004).

5.1.2 Water

Moody and Field reported the first measurements of PFOA in groundwater in 1999 (Moody *et al.* 1999). They used a GC/MS method and obtained a limit of quantitation (LOQ) of 36 ppb and a limit of detection (LOD) of 18 ppb. Recent publications in water matrices using LC/MS or LC/MS/MS report LOQs ranging from 0.1 ppt to 1 ppb and LODs ranging from 5 ppq (pg/L) to 7.8 ppt (ng/L). Appendix A-Table 1 summarizes PFOA measurements in the water matrix.

In general, natural water matrices are simpler matrices than most other natural matrices (*e.g.*, sludge, soil) for the determination of water-soluble species such as PFOA. Since PFOA or its salt is often used as a fluoropolymer processing aid in the production of perfluoropolymers and since perfluoropolymers are used in laboratory equipment, sample preparation and background level determination issues are important to address (Fluoropolymers Manufacturers Group 2003). Good chromatographic separation (to assure there are no co-eluting peaks) or use of isotopically enriched standards is important, especially at low quantitation levels. Isotopically enriched standards were used in a rainwater study (Loewen *et al*. 2005) although only one rainfall event was captured. When extensive concentration of samples is involved in the analytical method, a validation using spiked standards is necessary to show effects of sample

concentration and extraction. In seawater (Yamashita *et al.* 2004), coastal water (So *et al.* 2004), and surface water (Saito *et al.* 2004) examples, standards were not processed through the sample concentration step. In the seawater example, spike recovery was determined for laboratory water at 1 ppt. In this example background levels of a perfluorinated compound were found but could not be explained by instrumental or laboratory equipment background. In the coastal waters example, the field quality samples appeared to have come from a different batch of samples from those reported and analyte recoveries were determined from distilled water. Recoveries ranged from 160 to 190%, suggesting a possible problem with this method. In the surface water example, blanks were concentrated less than the samples (*i.e.*, samples and blanks were not treated the same way) and an external calibration was used. In many cases not enough information is available in publications to understand the level of analytical method validation.

A wastewater treatment plant (influent, effluent, and river water at point of discharge) was screened for eight perfluorooctane surfactants including perfluorooctanoate (Boulanger *et al*., 2005). Greater than 80% PFOA signal suppression was observed for the influent sample extracts. Field spike recovery was only 16%. Additional filter steps were able to remove the signal suppression problem but the recoveries were still too low to report. Effluent and river water did not experience signal suppression.

Six-wastewater treatment plants were studied to determine the mass loading and fate of several perfluoroalkyl surfactants (Sinclair *et al*., 2005). Since matrix effects are known to cause either ionization suppression or enhancement in electrospray MS/ MS, both standard addition and post-column infusion were used to investigate this phenomenon. In this study only ionization suppression was observed for some of the long-chain perfluorocarboxylic acids, but it did not significantly affect quantitation. In all cases perfluorooctanoate (PFO) was consistently found in the procedural blanks and the inter sample methanol injections. This background was subtracted from the calibration curves and the samples.

A global survey of perfluorinated acids in oceans reviewed sources of background levels of perfluorooctanoate observed in ocean water sampling and analysis (Yamashita *et al*., 2005). Fluoropolymers were not used in the analytical system since they could be a potential source of perfluorooctanoate (PFO) background since perfluorooctanoate salts are often used as fluoropolymer processing aids. Procedural blanks were used to identify the sources of contamination and to help eliminate them. LC tubing was replaced with either stainless steel or polyetheretherketone (PEEK) tubing and solvent degasser hardware and valves were isolated from the LC system. Vial caps were replaced with polyethylene and polypropylene tubes were used for sample preparation. Solid-phase extraction (SPE) cartridges and filters were also checked and washed as necessary to reduce or eliminate background levels. In addition to the precautions introduced into the sampling and analysis equipment, matrix

spikes, field blanks, procedural blanks, instrument blanks, and continuing calibration verification with every set of 20-25 samples was used to determine the background and interferences. The highest concentration of PFOA found in procedural blanks passed through the entire analytical procedure including SPE cartridges was 5.2 pg/L.

The ratio of perfluoroheptanoic acid (PFHpA) to PFOA in surface waters was suggested as a means of differentiating between atmospheric and non-atmospheric deposition sources (Simcik *et al*., 2005). Samples were filtered through 0.4-μm filters then extracted with a C_{18} SPE dried with nitrogen, then eluted with methanol. The residue was reconstituted with methyl t-butyl ether then cleaned up via liquid/solid chromatography (fluorous silica gel). The sample was eluted from that column with methanol and PFO determined via LC/MS. Extensive quality assurance data was reported to demonstrate the viability of the method.

5.1.3 Air

Techniques for measuring perfluorinated compounds in air are still under development. The determination of fluorine-containing compounds in air had been generally limited to charcoal adsorption followed by Wickbold torch determination of total fluorine (Kissa 1986) or measurements of volatile hydrofluorocarbons, chlorofluorocarbons, or chlorofluorocarbons, either directly or after adsorption, via gas chromatography (Bertsch *et al.* 1974, Cox *et al.* 1982, Grunsrud *et al.* 1975, 1975a, Lovelock 1972, Reinke at al. 1985, Russell *et al.* 1977, Schlitt *et al.* 1980). Martin *et al.* 2002 reported a method for the collection and determination of nine fluorine-containing neutral compounds by high-volume air sampling followed by extraction and then gas chromatography mass spectrometry. In 2004 Shoeib *et al.* investigated perfluoroalkyl sulfonamides in indoor and outdoor air (Shoeib *et al.* 2004). Stock *et al.* reported data from a six-city sampling campaign in North America where both perfluorinated alcohols and amides were found (Stock *et al.* 2004). PFOA was not determined in any of these studies.

PFOA was measured in airborne dust collected on quartz membrane filters near two Japanese cities (Harada 2005). Although no data were available for the blank concentrations, PFOA levels were reported to be significantly higher than the blanks. No particle size speciation was performed.

Another method for the determination of PFOA in air samples (Kaiser *et al.* 2005a) was used to measure perfluorooctanoate in ambient air near a manufacturing facility (Barton *et al.* 2005). Since PFOA has a vapor pressure of 128 Pa at 59ºC (Kaiser *et al.* 2005b), this method also allowed for the determination of PFOA in the vapor phase. Size speciation was accomplished using a high-volume cascade impactor. A summary of PFOA measurements in air is given in Table 2.

Determination of PFOA in air involves a higher level of complexity compared with determinations in water. Since PFOA has a finite vapor pressure near ambient

temperatures (Kaiser 2005b), it is important that the method validation include analyte breakthrough evaluation. Since PFOA is also very soluble in water (4.4 g/L at 25ºC) (Shinoda *et al.*1972), analyte retention at the expected relative humidity range of the measurement should also be determined. An evaluation guideline that includes these and other measurement considerations is available (U.S. OSHA 2002).

5.1.4 Biota

A wide variety of biological matrices have been analyzed for PFOA (See Table 3 and also "Environmental Concentrations" section.) Many of the initial methods focused on other perfluorinated compounds and were not optimized for PFOA determination. Initially methods were not available to address the interference from blank levels of PFOA in the analytical systems. Standards were not well characterized and researchers may not have known the distribution of branched and linear PFOA present in standards and samples. Also with mobile sources (wildlife), it is often difficult to determine the source of the analytes. For soil and sediment measurements, homogeneity is often a complicating factor in determining a representative sample. In reviewing the literature it is obvious that there is little agreement on the specification of reporting levels (LOD, LOQ). Details on spike recovery and blanks are often not included. As the analytical techniques continue to evolve, as isotopically enriched standards are introduced into the measurement protocol, and as round-robin studies give an indication of the quality of the measurements, the confidence level in the measurement s of PFOA in the environment will be better defined.

A screening method was developed using polar cod and glaucous gull livers (Berger *et al*., 2005). The method uses an extraction solvent with the same composition as the LC mobile phase to avoid the reconstitution step. The extract is coarsely filtered first through a facial tissue covering the tip of a Pasteur pipette, then through a centrifugal filter. The method works well for PFO but did not work well at low levels for the less polar analytes.

An ion-pairing method was used to determine perfluorocarboxylic acid levels in bottlenose dolphin plasma (Houde *et al*., 2005). Either dual 13C PFOA or perfluoroheptanoic acid was used as an internal standard.

Polar bear liver was analyzed for PFO using an ion-pairing agent and LC/MS/MS (Smithwick *et al*., 2005). Background levels were subtracted from the sample concentrations.

5.1.5 Soil, Sludge, and Sediment

PFO and other perfluoroacid anions were measured in sludge from six wastewater treatment plants (Sinclair *et al*., 2006). The extraction method was similar to that used by Higgins et al. (Higgins *et al*., 2005). As noted above, PFO background was found in all samples and in solvent blanks, so it was subtracted from the samples and calibration curves.

A simple and efficient method for extraction of domestic sludge and sediment was developed that uses a liquid solvent extraction (1% acetic acid then 90:10 methanol and 1% acetic acid)(Higgins *et al*., 2005). After centrifugation the samples are passed through a C_{18} SPE extraction cartridge, washed, then a dual ^{13}C internal standard added prior to LC/MS/MS determination. A summary of the soil, sludge, and sediment reports is given in Table 4.

5.1.6 Other Media and related reports

Although not developed for determining PFOA in the natural environment, several methods have appeared in the peer-reviewed literature that might provide useful information. Water, methanol, sweat simulant, and saliva simulant were used to extract PFOA from textile and carpet (Mawn *et al.* 2005). A method to optimize PFOA extraction from polytetrafluoroethylene polymer was developed using pressurized solvent extraction and reflux extraction (Larsen *et al,* 2005). A capillary electrophoresis with ultraviolet detection method was developed to measure higher levels of PFOA (Wojcik *et al.* 2005). A LC/MS method for the determination of the ammonium salt of PFOA in air was also reported (Reagen *et al.* 2005).

One paper was published on the physicochemical properties of perfluorocarboxylic acids (Kaiser 2005b). Studies involving gas-phase thermolysis of ammonium perfluorooctanoate (APFO) (Krusic *et al*. 2004) and PFOA (Krusic *et al*. 2005) and using gas-phase nuclear magnetic resonance (NMR) were reported. A different NMR study used ^{19} F NMR to correlate PFOA structure with environmental properties (Ellis *et al*. 2004). A thermal degradation study of treated textiles showed no detectable PFOA was formed under incineration conditions (Yamada *et al.* 2005).

5.1.7 Analytical Determination of Perfluorooctanoic Acid Uncertainty

Despite the limitations of the analysis and the number of investigations reported, the trend is to strive to lower reporting limits. Determination of PFO in different sample types (tissue, blood, *etc.*) measurement of temporal trends, and correlation with abiotic environmental concentrations are essential to our understanding the disposition of PFOA in the environment. At higher concentration levels (*e.g.,* >10x LOQ) the data reported to date are probably quite reliable. At the lower levels (<3X LOQ) the analytical issues need to be addressed thoroughly and reported to ensure data reliability and accuracy.

Low-level determination of any analyte necessitates special attention. Fluorinated surfactants exhibit chemical and physical properties quite different from their hydrogenated analogs, with important implications for the analysis of these materials (Kissa 2001). Sample-collection and sample-preparation protocols must be carefully designed to ensure that no analyte is lost and that no interfering contaminants are

introduced. The limits on reliable quantitation must be rigorously defined and observed, based on determination of suitable standards and blanks. The fitness of the method for measurement of fluorosurfactants must be objectively evaluated (Thompson 1996) and the method thoroughly validated, including an investigation of subtle effects, such as sorption losses or contamination from containers, reagents, or laboratory equipment. Validation considerations should include a matrix-based standard curve with a minimum of five points, accuracy and precision demonstration at low, middle, and high concentration levels, and storage stability (*e.g*., U.S. FDA 2001). Since PFOA may be present in the fluoropolymer parts of laboratory equipment, blanks (*e.g*. solvent, reagent, method, field, trip) are essential. Since co-eluting peaks can cause suppression or enhancement of the PFOA peak via LC/MS/MS, it is essential that a good separation is achieved or that an isotopically enriched PFOA is used to demonstrate if suppression or enhancement occurs.

The selection of a standard is also important since PFOA can be synthesized by either electrochemical fluorination (ECF) or by the telomerization process. The ECF process can form from 20 to 30 % branched "impurities" (Abe *et al.*1982). Telomerization produces impurities differing by two-carbon atoms (Kissa 2001a).

Ideally a secondary method should also be used to evaluate the dependence of the method on the quantification. The secondary method should rely on a different property of the analyte. Moody (Moody *et al.*2001) used nuclear magnetic resonance spectroscopy (NMR) and LC/MS/MS to compare analytical method results from samples from a spill of 22,000 L of fire-fighting foam into a creek. Although the levels of fluorine-containing species were high, the NMR and LC/MS/MS results varied from approximately a factor of 3 to 7 within a sample pair.

Note that the literature references included here covered a long time period in which an evolution in equipment and methods occurred. Since many of the issues concerning measurement of PFOA were unknown, insufficient information was available to evaluate methods properly. When all the studies are assessed according to today's criteria for sampling protocol, technique suitability, and method validation, earlier studies may appear to suffer by comparison.

5.1.8 Round Robin and ISO Standard Methods

In 2005 thirty-eight laboratories participated in the first worldwide interlaboratory study on perfluorinated compounds in human and environmental matrices (Van Leeuwen *et al*., 2005). The study included the determination of perfluorooctanoate and other perfluorinated compounds in aqueous standards, fish muscle tissue, fresh water, clean fish extract, human plasma, and whole blood. The data were evaluated by determining "z" scores based on the Cofino model (de Boer *et al.*, 2002). Laboratories from Belgium, Canada, Denmark, Germany, Italy, Japan, Norway, Sweden, Switzerland, The Netherlands, the United Kingdom, and the United States participated. Experience ranged from just a few months to over five years in handling the types of samples provided.

In general the results indicated that the more complex the matrix, the more difficult it was for the laboratories to obtain satisfactory data as indicated by a z score of <2. On the 8.4 ng/mL (ppb) study standard, 21 of 33 reporting laboratories got satisfactory scores, 2 obtained "questionable" scores (viz., 2<z<3), and 10 received an unsatisfactory score (viz., z>3). For fish liver extract, 10 of 25 participating laboratories got satisfactory scores; for fish tissue, 5 of 20 got satisfactory scores; and for fresh water, 4 of 18 got satisfactory scores. Laboratories did not tend to show consistent performance across the sample types, sometimes doing well with one matrix and poorly with another. There was no correlation between the level of experience and performance. There was also no bias between laboratories that used MS versus those using MS/MS. Differences between laboratories on extraction and clean-up procedures were thought to have a large effect, especially for the more complex matrices. Another study is being planned for 2006.

These results of the interlaboratory study suggest that more work is needed to establish appropriate, rugged and reliable analytical methods for perfluorooctanoic acid determinations, even for the simpler matrices. The statistics noted above are a best case scenario, that is, laboratories that provided data undoubtedly did their best to get accurate and precise results. Some laboratories delayed or withdrew from the study after having paid the fee due to "technical problems or tight schedule" so that their results are not included in the report.

Since a well-defined validated method is necessary to get good interlaboratory agreement, scientists from twelve countries gathered at an ISO meeting in Tsukuba, Japan, in June 2005 to address this task. They accepted a work item proposal to produce a standard method for the determination of both PFOS and PFOA in unfiltered water samples using solid-phase extraction and LC/MS. That task is still underway. The next matrix that they will address will probably be air.

5.2 Analytical: Literature Cited

Additional Literature Cited DuPont-19567

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5.3 Analytical: Appendix A

(Tables 1-5)

Table 1: Determination of PFOA in water

Matrix (reference)	Technique*	LOD	LOQ	Concentration Factor	Calibration Range	Spike Recovery %
Ground water (Moody *et al.* 1999; Moody 2003)	GC/MS	18 ppb	36 ppb	55-200	3.6 to 1080 ug	73-90
Etobicoke Creek (Moody *et al.* 2002)	LC/MS/MS	1 pg	9 ppt	100	0.46 to 325 ppb	80-100
Tennessee River(Hansen *et al.* 2002)	LC/MS/MS	5 ng/L	10-to 25 ng/L	8	10 to 5000 ng/L	112
Great Lakes (Boulanger *et al.* 2004)	LC/MS/MS	6pg/mL	13	2500	1 to 500 ng/L	109
Seawater (Yamashita *et al.* 2004) and (Taniyasu *et al.* 2004a)	LC/MS/MS	5 ppq	1 or 100 ppt	2000-5000	1 to 500 ppt; 0.1 to 20 ppb	124 (C18); 147 Oasis
Coastal water (So *et al.* 2004)	LC/MS/MS	not reported	0.02 ppt	400-2500	0.02 pg/mL (upper level not reported)	170
Surface water (Saito *et al.* 2004)	LC/MS	0.06 ppt	0.1 ppt	1000	0 to 2 ppt; 5-150 ppt	92-99
Rainwater (Loewen *et al.* 2005)	LC/MS/MS	7.2 ppt	1 ppb	4000	1 to 50 ppb	not detected
Water (Risha *et al.* 2005)	LC/MS/MS	Not reported	25 ppt	8	25 to 1000 ppt	not reported
Water (Alzaga *et al.* 2004)	GC/NCI-MS*	0.1 µg/L	0.34 µg/L	SPME**	0.035 to 150 µg/L	73 to 90
Water sea, lake, snow, run-off (Yamashita *et al.*2004b)	LC/MS/MS	not reported	not reported	not reported	not reported	not reported

Water: lake (Sinclair *et al.* 2004)	LC/MS/MS	8 ng/L	25 ng/L	50	not reported	Not reported
Water: sea (Caliebe *et al.* 2004)	LC/MS/MS	not reported	0.05 to 0.5 ng/L	45,000	not reported	not reported
Water: rain, sea, lake, effluents (Berger *et al.* 2004)	LC/MS	not reported	not reported	not reported	not reported	not reported
Wastewater (Boulanger *et al.* 2005)	LC/MS/MS	not reported	6 pg/mL (ppt)	200:1 and 600:1	0.5 ng/mL to 250 ng/mL (ppb)	16 - 86
Ocean water (Yamashita et al.2005)	LC/MS/MS	not reported	not reported	not reported	not reported	not reported
Surface water (Simcik et al., 2005)	LC/MS	0.29 and 0.58 ng/L (ppt)	not reported	8888:1 and 17777:1	5 to 100 ng/mL (ppt)	93 -112
Wastewater (Sinclair et al., 2005)	LC/MS/MS	not reported	2.5 ng/L		0.1 to 100 ng/mL (ppt)	70 - 130
Water (Taniyasu et al., 2005)	LC/MS/MS	not reported	several pg/L	not reported	not reported	>80
Freshwater and marine water (deVoogt et al., 2005)	LC/MS	0.08 ug/L	not reported	not reported	not reported	not reported
Water (Kurunthachalam et al., 2005)	LC/MS/MS	not reported	not reported	500:1	not reported	91 -114
Wastewater (Crozier et al., 2005)	LC/MS/MS	1ng/L	not reported	not reported	not reported	92 -106
Lake water (Furdui et al., 2005)	LC/MS/MS	1 - 4 ng/L	not reported	1:1	0.5 - 100 ng/L	not reported
Streams (Rostkowski et al., 2005)	LC/MS/MS	not reported	0.5 ng/L	not reported	not reported	95
Shallow sea	LC/MS/MS	0.8 - 10	not	not reported	not reported	not

water (Nakata et al., 2005)		ng/L	reported			reported
Water (Taniyasu et al., 2005a)	LC/MS/MS	0.02 pg	0.02 pg		not reported	not reported
Ground water (Kaiser et al., 2005a)	LC/MS/MS	10 ppt	50 ppt	8:1	25 ppt to 1000 ppt	70-130
Wastewater (Sinclair et al., 2005)	not reported	not reported	not reported	not reported	not reported	not reported
Sea water (Theobald 2005)	LC/MS/MS	not reported	5 - 30 pg/L	not reported	not reported	not reported
Lake water (Furdui et al., 2005a)	LC/MS/MS	not reported	ppt	not reported	1:01	not reported
Water (Taniyasu et al., 2005b)	LC/MS/MS	not reported	1 pg	not reported	not reported	>80
River water (Falandysz et al., 2005)	not reported	not reported	0.1 ng/L	not reported	not reported	not reported
Rain water (Scott et al., 2005)	GC/MS	not reported	not reported	not reported	not reported	not reported

*GC/MS, gas chromatography/ mass spectrometry; LC/MS/MS, liquid chromatography tandem mass spectrometry; NCI-MS, Negative ion chemical ionization mass spectrometry; SPME, solid-phase microextraction

Table 2: Determination of PFOA in air

Media	Validated range	Technique	Spike recovery (% +/- s.d.**)
Quartz filter (Harada et al., 2005)	not reported	LC/MS*	89.4 +/- 3.91
OVS tube (Kaiser *et al.* 2005a,c,d,e)	0.474 to 47.4 ug/m^3	LC/MS	97.7 +/- 6.28
Cellulose filter (& OVS tube, see above) (Barton *et al.* 2005)	1 pg/m^3 to 50 pg/m^3 (24 hour sample at 1.2 m^3/min)	LC/MS	96

*LC/MS, liquid chromatography/mass spectrometry
** s.d., standard deviation

Table 3: Determination of PFOA in biota

Matrix (reference)	Technique	LOD	LOQ	Calibration Range	Spike Recovery %
Wildlife (Giesy *et al.* 2001)	LC/MS/MS	not reported	2.5 to 180 ng/g wet	not reported	not reported
Liver: mink; otter (Kannan *et al.* 2002)	LC/MS/MS	not reported	4.5 to 75 ng/g	not reported	53 to 140
Liver: marine mammals; fishes; birds Blood: fish (Kannan et al 2002a)	LC/MS/MS	not reported	2.5 ng/mL	not reported	<40 (salmon); 90 (sea eagle); 70 (seal)
Liver: mink and river otters (Kannan *et al.* 2002b)	LC/MS/MS	not reported	4.5 to 75 ng/g	not reported	53 to 140
Liver: rat; rabbit (Hansen *et al.* 2001)	LC/MS/MS	1.0 ppb	5.0 ppb	50 to 1000 ppb	87 +/- 12
Liver: rat (Ohya *et al.* 1998)	LC with fluorescence detection	1 pmol/mg	not reported	0.1 to 10 nmol	93.6 to 94.0
Tissues: rat (Kudo *et al.* 1998)	GC with electron-capture detection	1 ng /injection	not reported	not reported	30
Sludge (Schroder *et al*. 2003)	LC/MS	0.48µg/mL	10 mg/kg	2 to 25 µg/mL	6 to 319
Liver, various (Martin *et al.* 2004a)	LC/MS/MS	2 ng/g	not reported	2.5 to 1000 pg	>80

Liver: marine mammals; fishes; birds (Bossi *et al.* 2005)	LC/MS/MS	7ng/g	12 ng/g	10-1000 ng/g	105
Liver: polar bear (DeSilva *et al.* 2004)	GC/MS	0.02 pg	not reported	not reported	not reported
Eggs: Guillemot(Holmstrom *et al*. 2005)	LC/MS/MS	3 ng/g	not reported	not reported	not reported
Liver: mice (Hoff *et al.* 2004)	LC/MS/MS	not reported	not reported	not reported	not reported
Tissues: fishes, pelicans (Johnson *et al.* 2004)	not reported	not reported	not reported	not reported	not reported
Liver: fish and marine mammal (Kallenborn *et al.* 2004)	LC/MS	0.6 to 1 ng/g	not reported	not reported	40 to 72
Plasma: turtle (Keller *et al.* 2004)	LC/MS/MS	not reported	not reported	not reported	not reported
Food web (Martin *et al.* 2004)	LC/MS/MS	2 ng/g	not reported	not reported	96 to 101
Liver: polar bears (Smithwick *et al.* 2005)	LC/MS/MS	2 ng/g	not reported	not reported	99.9
Food web (Tomy *et al.* 2004)	LC/MS/MS	0.2 ng/g	Not reported	10 to 300 pg/µL	98 to 110
Liver: marine mammal (De Vijver *et al.* 2003)	LC/MS/MS	not reported	10 to 110 ng/g wet weight	not reported	not reported

Blood: bovine (Guruge *et al.* 2004)	LC/MS/MS	not reported	not reported	not reported	92
Marine: liver and blood (Corsolini *et al.* 2004)	LC/MS/MS	not reported	3 to 20 ng/mL	0.5 to 100 ng/mL	Not reported
Polar cod and glaucous gull livers (Berger et al., 2005)	LC ToF MS	1.25ng/g (cod); 1.28 ng/g (μl)	not reported	not reported	84 (cod); 83 (gull)
Bottlenose dolphin plasma (Houde et al., 2005)	LC/MS/MS	not reported	0.5 ng/g	not reported	89.4
Polar bear liver (Smithwick et al. 2005)	LC/MS/MS	2.3 ng/g	not reported	not reported	53 - 130
Harbor seal tissues (Van de Vijver et al., 2005)	LC/MS/MS	not reported	1.39 - 62 ng/g	not reported	not reported
Glaucous gull plasma, liver, brain, and eggs	LC/MS/MS	not reported	not reported	not reported	59 - 134
Lake aquatic organisms (Kannan et al., 2005)	LC/MS/MS	not reported	not reported	0.10 - 750 ng/mL	<50
Blood and liver (Taniyasu et al. 2005)	LC/MS/MS	not reported	several pg/g	not reported	>80
Water (Kurunthachalam et al., 2005)	LC/MS/MS	not reported	not reported	not reported	80-108
Shallow	LC/MS/MS	3.0 ng/g	not	not reported	not

coastal water organisms (Nakata et al., 2005)			reported		reported
Burbot liver (Tomy et al., 2005)	LC/MS/MS	not reported	not reported	not reported	>85
Beluga liver (Tomy et al. 2005a)	LC/MS/MS	0.3 ng/g	not reported	not reported	not reported
Mussels and oysters (So et al., 2005)	LC/MS/MS	not reported	not reported	not reported	92.5
Calf serum and liver (Guruge et al., 2005)	LC/MS/MS	49 pg/mL	not reported	not reported	96, 98
Fish and bird livers (Sinclair et al., 2005)	not reported	not reported	not reported	not reported	not reported
Biological matrices (Marlinsky 2005)	GC/MS	not reported	not reported	not reported	not reported
Plant tissue samples (Powley et al., 2005)	LC/MS/MS	not reported	5 ppb	not reported	80 - 110
Fish and water fowl blood (Gulkowska et al., 2005)	LC/MS/MS	not reported	0.05 ng/mL	not reported	not reported

Table 4: Soil, sludge and sediment

Matrix (reference)	Technique	LOD	LOQ	Concentration Factor	Calibration Range	Spike Recovery %
Wastewater sludge (Sinclair et al., 2006)	LC/MS/MS	not reported	2.5 ng/L	0.1g:1mL	0.1 to 100 ng/mL (ppt)	not reported
Sludge and sediments (Higgins et al., 2005)	LC/MS/MS	0.011 ng/g sediment ; 1.0 ng/g sludge	not reported	1g:10 mL	0.01 to 50 pg/uL	88 -94 (sediment) ; 71 - 80 (sludge)
Sediments (Lucaciu et al., 2005)	LC/MS/MS	not reported	not reported	5g:0.5 mL	not reported	50-80
Sediments (de Voogt et al., 2005)	LC/MS	0.4 ng/g	not reported	not reported	not reported	not reported
Sediment(Kurunthachalam et al., 2005)	LC/MS/MS	not reported	not reported	15g: 1 mL:	not reported	81 -109
Wastewater (Crozier et al., 2005)	LC/MS/MS	0.1 ng/g	not reported	not reported	not reported	not reported
Sediment (Nakata et al., 2005)	LC/MS/MS	0.10 ng/g	not reported	not reported	not reported	not reported
Sludge and sediments (Higgins et al., 2005a)	LC/MS/MS	0.7 - 2.2 ng/g	not reported	not reported	not reported	not reported
Wastewater (Schultz et al., 2005)	LC/MS/MS	not reported	not reported	not reported	not reported	not reported
Sediments (Lucaciu et al., 2005a)	LC/MS/MS	not reported	not reported	not reported	not reported	not reported

Sediments and soils (Ellington et al., 2005)	not reported	not reported	not reported	not reported	not reported	not reported
Soil and sediment (Szostek et al. 2005)	not reported	not reported	not reported	not reported	not reported	70 - 120
Sludge (Crozier et al., 2005a)	LC/MS/MS	not reported	not reported	not reported	not reported	not reported
*Liquid chromatography (LC)						
Mass Spectrometry (MS)						
Tandem MS (MS/MS)						
Gas chromatography (GC)						

Table 5: Other media

Matrix (reference)	Technique	LOD	LOQ	Calibration Range	Spike Recovery %
Extraction of PTFE* polymer (Larsen *et al.* 2005)	Reflux and pressurized solvent; LC/MS/MS	not reported	0.5 ppb	0.1 ppb to 150 ppb	0 to 106%
Extraction of textile and carpet (Mawn *et al.* 2005)	LC/MS/MS	not reported	0.08 ng/mL	0 to 50.0 ng/mL	95.1 to 112
APFO** in air (Reagen *et al.* 2004)	LC/MS	144 ng/mL	479 ng/mL	Not reported	81 to 90
CE*** (Wojcik *et al.* 2005)	CE	13µg/mL	not reported	0.1 to 9.5 mM/L	not applicable
House dust (Kubwabo et al., 2005)	LC/MS/MS	2.29 ng/g	7.29 ng/g	25 to 1000 ng/g	100.7
Food packaging (Begley et al., 2005)	LC/MS	not reported	not reported	not reported	>90
Paper, textile, and carpet (L'empereur et al., 2005)	LC/MS/MS	10 ppt	50 ppt	25 - 500 ng/L	70-120
Plasma (Hoppe et al., 2005)	NCI GC/MS	not reported	1 ug/L	1 - 100 ug/L	not reported
House dust (Strynar et al., 2005)	LC/MS/MS	not reported	0.1 ug/g	not reported	not reported
Consumer articles (Powley et al., 2005 a)	LC/MS/MS	not reported	not reported	not reported	88, 84-98
Consumer articles (L'empereur	LC/MS/MS	not reported	not reported	not reported	98.9

et al. 2005a)					
Food (Schlummer et al., 2005)	LC/MS/MS	1 - 2 ng/g	not reported	not reported	80 - 120

*PTFE, polytetrafluoroethylene
**APFO, ammonium perfluorooctanoate
***CE, capillary electrophoresis

6.0 Summary / Conclusions

6.1 Summary / Conclusions

Based on studies in the available literature, PFOA will meet international criteria (see page ix, Table 1) for persistence based on expected half-lives of PFOA via biodegradation, hydrolysis, and photolysis under environmentally relevant conditions. It is anticipated that water will be the predominant environmental compartment in which PFOA resides. In regards to sludges, soils, and sediments, the expectation is that adsorption will be very limited and any PFOA associated with these environmental matrices will likely be found in the water phase of sludges, soils, and sediments and/or perhaps weakly adsorbed by electrostatic interactions.

However, there are still significant uncertainties in regards to the environmental fate of PFOA including: 1) sources of PFOA in the environment; 2) potential for biotransformation in soil and sediments under varying environmental conditions and anaerobic sludges; 3) transport / distribution mechanisms; and 4) potential for oceans to be predominant sinks.

The available data indicate that BAF and BCF values for PFOA are below all regulatory levels that would trigger concern for bioconcentration and bioaccumulation. In addition, the available evidence indicates that PFOA does not biomagnify through the foodchain. Therefore, while PFOA appears to be environmentally persistent, PFOA is not bioaccumulative based on relevant data and regulatory B criteria.

Based on international PBT criteria such as the EC criteria for Inherent Toxicity (T_i), which indicate that a substance is inherently toxic if its acute toxicity is < 1 mg/L or its chronic toxicity is < 0.1 mg/L, PFOA is not inherently toxic.

The available acute and chronic aquatic toxicity data for PFOA also indicate that it is of low to medium concern for toxicity (i.e., hazard) to freshwater algae, invertebrates, and fish based on data from laboratory studies and the ranking scheme used by U.S. EPA. However, no data are available to assess the aquatic toxicity of PFOA to marine algal, invertebrate or fish species. There are also no PFOA toxicity test data available for either terrestrial wildlife or avian species.

Current analytical methods make it possible to detect extremely low concentrations (i.e., high parts-per-trillion to low parts-per billion range) in various environmental matrices. The first reports of PFOA in environmental samples in 1999 have been followed by reports using continuously improving analytical sensitivity, hence the number of non-detects is being replaced by measurable, but very small amounts being detected. Although the total number of environmental samples analyzed is growing, there currently is not enough data in any one matrix with significant samples to clearly define temporal or geographical trends among the various environmental media (including biota). Continuing studies, which incorporate more defined sampling strategies employing currently available analytical technology, should help define temporal / geographic trends. The data available to date do not

seem to indicate that PFOA collects in any environmental media other than the aquatic environment, which appears to be the likely sink.

Analytical methods for the determination of PFOA in various matrices continue to evolve. It is difficult to make comparisons between literature reports, especially over time, since details such as types of standards, methods for determining LOD and LOQ, spike recovery and blank types and results are not available or are defined inconsistently. Generally the reports at the higher levels are probably reliable. At lower levels, however, analytical issues concerning reporting limits, blanks, standards, and representativeness of sample need to be addressed.

7.0 Acknowledgements

7.1 Acknowledgements

The authors of this paper would like to acknowledge the invaluable contributions to this paper from the following people:

Nancy S. Selzer
Gerald L. Kennedy, Jr.
Robert W. Rickard