PFOS AND PFOA IN DUST FROM STOCKHOLM MICROENVIRONMENTS

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Introduction

Perfluorinated chemicals (PFCs) are chemicals used in the production of a wide variety of products. Major fields of application include surfactants, surface protection (e.g., for textiles, carpets, and upholstery), paper treatment (e.g., for food packages), and lubricants[1]. Perfluorooctane sulfonate (PFOS) and perfluorooctanoate (PFOA) have received wide attention because they bioaccumulate[2;3] and are extremely persistent in the environment.
PFOS is the predominant PFC in wildlife and humans, but the ratio between PFOS and PFOA is much higher in wildlife than in humans[4], which may indicate different exposure sources or routes. Household dust has been found to contain measurable amounts of PFOS, PFOA[5-7]. There are no data for PFC concentrations in dust in Sweden. This study's aim was to determine the level of PFOS and PFOA in dust samples from day care centers, homes, offices, apartments and cars from Stockholm since dust could be a potential source of exposure to chemicals.

Methods

Dust samples were collected from 10 houses, 38 apartments (from 11 different buildings), 10 day care centers, 10 offices from different buildings and 5 new cars (4 makes) from Stockholm City. Apartment buildings were chosen so that half of the apartments sampled had characteristics of "sick building syndrome" and the other half were classified as "healthy homes" Dust samples were collected using cellulose filters in styrene-acrylonitrile holders inserted in a polypropylene nozzle (Krim. Teknisk Materiel AB, Bålsta, Sweden), which was attached to the intake nozzle of an industrial strength vacuum cleaner[8]. Sampling was done from surfaces at least one meter above the floor, such as bookshelves, moldings and counters, in order to eliminate dirt, gravel and sand. Dust was only available from 5 cars of 4 different makes. Surrogate standards of ^{13}C-PFOA and ^{18}O-PFOS were added to dust samples together with approximately 10 mg of Envi-Carb and 3 ml of methanol. The samples were extracted twice in Methanol by ultrasound for 10 min. The combined extracts were concentrated to 500 µl and 500 µl of 4 mM ammonium acetate buffer in water was added to the extract. The combined extract and buffer were transferred to LC-vials, pre-spiked with injection standard (3,5-bis(trifluoromethyl) phenyl acetic acid), with a syringe equipped with a 0.45 µm syringe filter (Pall Life Sciences, Ann Arbor, US). Samples were then analyzed using HPLC/MS. PFOS and PFOA were measured using selected ion monitoring (SRM-MS/MS) with argon as reaction gas, monitoring the transitions 499>80 for PFOS and 413>369 for PFOA. All samples were prepared and analyzed in sets of 30, including three solvent blank samples, three QC-samples (Standard Reference Material® SRM 2585, National Institute of Standards and Technology, Technology Administration, Department of Commerce, US) and three surrogate reference samples resulting in 21 actual samples per series. Mean recoveries calculated from spiked dust samples (n = 9) were 74 ± 5% for PFOS and 78 ± 4% for PFOA.

Results and Discussion

The mean concentrations (ng/g) ± standard deviations of the NIST SRM dust samples (n=11) analyzed were 1990 ± 78 and 673 ± 26 for PFOS and PFOA, respectively. PFOS and PFOA were found in dust samples from all microenvironments. The median concentrations of PFOS and PFOA are presented in and Figure 1. The median concentrations in the different microenvironments are within one order of magnitude of each other, and the ranges within each microenvironment were generally not as large as those seen for BFRs[9]. Highest PFOS concentrations were seen in offices (110 ng/g dw), similar but lower concentrations were seen in houses (39 ng/g dw) and day care centers (32 ng/g dw), and lowest concentrations were seen in apartments (19 ng/g dw) and cars (11 ng/g dw). For PFOA, the concentrations were more similar between different microenvironments, with highest concentrations found in apartments (78 ng/g dw) and offices (70 ng/g dw). Offices have higher median PFOS concentrations than PFOA, while houses, apartments, day care centers and cars have higher median PFOA concentrations than PFOS.

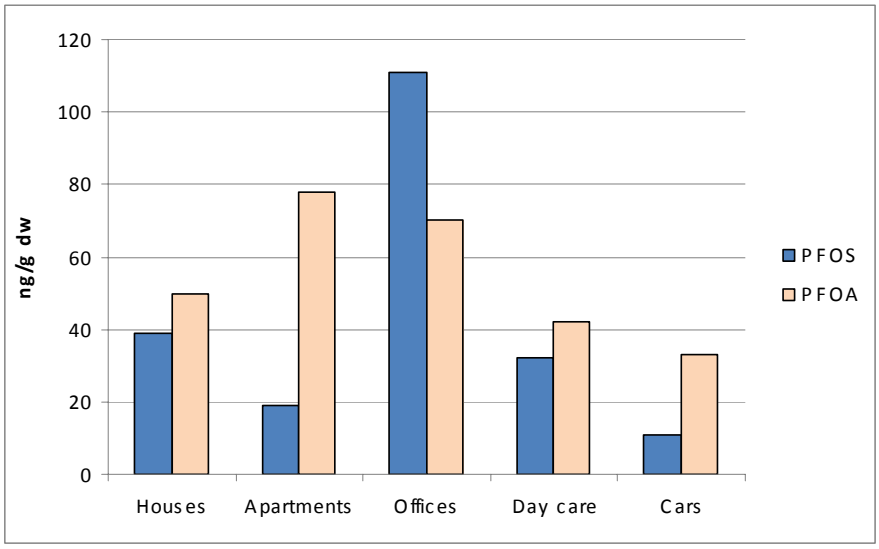

Fig. 1. Median concentrations of PFOS and PFOA in dust from houses, apartments, offices, day care centers and cars.

Correlation between PFOS and PFOA

A statistically significant correlation between PFOS and PFOA concentrations (log-transformed data) in dust was found when data from all microenvironments was included (Fig. 2). Otherwise, no statistically significant correlations were seen when dust samples were compared for houses, apartments, offices or day care centers, separately. Previous studies of PFOS and PFOA in dust have also found statistically significant correlations between these compounds[5;7]. The limited number of dust samples from cars made it impossible to carry out correlation analyses for these.

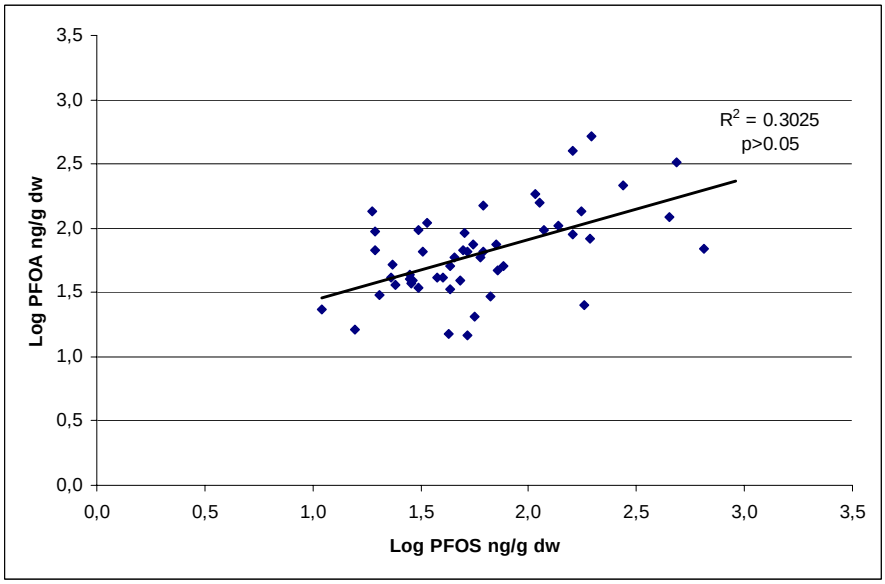

Fig. 2. Correlation between log-transformed PFOS and PFOA concentrations in all dust samples.

Comparisons between microenvironments
Median PFOS concentrations are highest in offices, but there are individual apartments with even higher concentrations than found in individual offices. For PFOA, the highest individual concentrations are found in some apartments. Houses and day care centers have much less variability in concentrations. Interestingly, there are significantly higher PFOA concentrations in dust from "healthy" apartments than in "sick" apartments. The significant correlation between PFOS and PFOA when all dust data are included indicates that these PFCs may be present in the same consumer products in the different microenvironments.

Comparisons to published data
There are no published data for PFOS or PFOA in dust samples from Sweden to compare our results with. In a study of 16 homes in Japan, median PFOS concentrations were 25 ng/g dw (range, 11-2500 ng/g dw) and median PFOA concentrations were 165 ng/g dw (range 70-3700)[5]. In a study of 67 homes in Canada, median PFOS concentrations were 38 ng/g dw (range 2.2-5070 ng/g dw) and median PFOA concentrations were 20 ng/g dw (range 1-1230 ng/g dw)[7]. When compared to these dust results, median concentrations of PFOS in Stockholm houses (39 ng/g dw) are similar or somewhat higher, but median PFOA concentrations (50 ng/g dw) are lower than in dust from Japanese homes, but higher than in dust from Canadian homes. For apartments, median PFOS concentrations (19 ng/g dw) are lower than in Japan and Canada, and median PFOA concentrations (78 ng/g dw) are lower than in dust from Japan, but higher than for dust in Canada.

There are no published data for PFOS or PFOA in dust from public microenvironments or in cars with which to compare our results. Compared to the Japanese and Canadian dust studies, the PFOS and PFOA concentrations in dust from day care centers are similar to those from houses so the same comparison is valid. For Stockholm offices, the median PFOS concentrations (110 ng/g dw) are higher than those from dust in Japanese and Canadian homes and PFOA concentrations (70 ng/g dw) are lower than in Japan but higher than in Canada.

Human exposure
PFOS and PFOA were recently analyzed in Swedish food baskets and concentrations were below detection limits making it difficult to compare dietary intake of PFOS and PFOA with estimated dust ingestion. Table 1 presents estimated intakes of PFOS and PFOA from dust ingestion only, calculated using USEPA exposure factors[10] together with the median and maximum concentrations found in dust from houses and apartments.[11] The exposure factors include mean and high dust ingestion estimates for adults of 4.16 mg/d and 100 mg/d, respectively, and for toddlers (6-24 months of age), 55 mg/d and 200 mg/d, respectively.

Table 1. Comparison of total intake estimates for PFOS and PFOA in ng/day for adults and toddlers. Values are the mean sums of dust ingestion for houses and apartments for the different scenarios.

	Mean dust ingestion scenario				**High dust ingestion scenario**			
	Adult	Toddler	Adult	Toddler	Adult	Toddler	Adult	Toddler
	Median	Median	Max	Max	Median	Median	Max	Max
PFOS	0.3	1.5	2	20	5	6	47	75
PFOA	0.3	3	2	20	7	12	47	75
Sum PFCs	**0.6**	**5**	**4**	**40**	**12**	**18**	**94**	**150**

The estimated intakes of PFOS and PFOA are similar. Both adults and toddlers are exposed to both PFCs from indoor environments. There are no data available on the absorption efficiency of these compounds in humans. Toddlers have higher intakes from inhalation and dust ingestion than adults in all scenarios. The majority of the population probably has a lower exposure to PFCs via dust ingestion, but the results using the worst case scenario indicate that there may be a small percentage of the general population that has a much higher exposure.

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References

1. Kissa, E. *Fluorinated Surfactants and Repellants*, Second edition ed.; Marcel Dekker: New York, 2001.
2. Martin, J. W.; Mabury, S. A.; Solomon, K. R.; Muir, D. C. G. *Environ Toxicol Chem* **2003,** *22*, 189-95.
3. Martin, J. W.; Mabury, S. A.; Solomon, K. R.; Muir, D. C. G. *Environ Toxicol Chem* **2003,** *22*, 196-204.
4. Hansen, K. J.; Clemen, L. A.; Ellefson, M. E.; Johnson, H. O. *Environ Sci Technol* **2001,** *35*, 766-70.
5. Moriwaki, H.; Takata, Y.; Arakawa, R. *JEM* **2003,** *5*, 753-57.
6. Katsumata, T.; Nakata, A.; Iwasaki, Y.; Ito, R.; Saito, K.; Nakazawa, H. *Bunseki Kagaku* **2006,** *55*, 955-61.
7. Kubwabo, C.; Stewart, B.; Zhu, J. P.; Marro, L. *JEM* **2005,** *7*, 1074-78.
8. Bornehag, C. G.; Lundgren, B.; Weschler, C. J.; Sigsgaard, T.; Hagerhed-Engman, L.; Sundell, J. *Environ Health Persp* **2005,** *113*, 1399-404.
9. de Wit, C. A.; Thuresson, K.; Björklund, J. *Organohal Compds* **2008,** *70, this conference*.
10. USEPA *Exposure Factors Handbook, Vol. 1*, U.S. Environmental Protection Agency, Washington, D.C., EPA/600/P-95/002: 1997.
11. USEPA *Child-Specific Exposure Factors Handbook*, National Center for Environmental Assessment: Washington, DC., EPA/600/P-00/002B: 2002.