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PFASs in house dust

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Scientific report

Preface

This report presents the sampling methodology and results from the project «PFASs in house dust", conducted by NILU on assignment from the Norwegian Environment Agency (ref. 15128082). The work has included collection of dust from six separate rooms in six different households. The dust samples were analyzed for 20 targeted anionic and volatile per- and polyfluorinated alkyl substances (PFASs) as well as for total extractable organic fluorine (TEOF). The samples were collected in the Oslo-area in Norway in August 2015. It is the intention to publish these results and further evaluations in a scientific journal.

The project leader at NILU was Pernilla Bohlin-Nizzetto who also collected the household dust samples and reported the results. Linda Hanssen and Dorte Herzke were responsible for the chemical analysis of PFASs. The analysis of TEOF was performed at University of Toronto by Dr. Leo Yeung.

Kjeller, November 2015

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Summary

NILU has, on behalf of the Norwegian Environment Agency, performed sampling and analysis of house dust from Norwegian households. The goal was to study concentration ranges, and variability between and within-houses of anionic and volatile per- and polyfluorinated alkyl substances (PFASs), including the regulated PFOA, as well as total extractable organic fluorine (TEOF). The sampling was done in six separate rooms in six different households. The analysis covered a suite of 20 targeted PFASs; ten of these were consistently detected in most samples, while the other ten were below detection limits in the major part of the samples. A range of the targeted PFASs were detected in all rooms except in one room in one household in which all PFASs, were below detection. The concentrations of individual PFASs as well as the sum of PFASs, were lower than in a previous study in Norway. The results show significant variability between houses for the anionic and volatile PFASs as well as for TEOF. For anionic PFASs, the results also indicate within-house variability with higher concentrations in dust from bedrooms (children and parents) and living rooms than in dust from bathroom, kitchen and entrances. For the volatile PFASs and TEOF, no significant difference between rooms were found. These results indicate that factors like building materials and consumer products (e.g., furniture, textiles etc.) affect the levels of PFASs in house dust, but the reason for the findings are not further evaluated in this report. Anionic PFASs seem to contribute significantly to the TEOF (10-100%) in house dust.

PFASs in house dust

1 Background

Per- and polyfluorinated alkyl substances (PFASs) comprise a wide range of compounds that have been produced and used in a wide range of industrial and consumer applications since the 1950s (OECD, 2006; Lehmler, 2005). There is increasing attention on PFASs from both the scientific community and policymakers due to their global spread in the environment, bioaccumulation potential, persistence and toxicity (EU, 2006; UN/ECE, 2010; Stockholm Convention, 2011).

PFAS-applications include a wide range of indoor related products such as consumer products, stain-proof coatings on furnishing and carpets, oil resistant coatings on food wrapping, non-sticking coating on cooking utensils and water resistance in clothing and outdoor materials (OECD, 2006; Lehmler, 2005). As a result, PFASs are found in indoor matrices such as house dust and air at high concentrations (Shoeib et al., 2005; Goosey and Harrad, 2011; Huber et al., 2011). The aim of this study was to evaluate PFASs concentrations in Norwegian house dust and to understand within-house and between house variability. In addition, the content of total extractable organic fluorine (TEOF) in house dust was evaluated to understand to what extent the targeted anionic PFASs contribute to the TEOF. No information about TEOF in indoor matrices is previously available in the literature.

2 Sampling methodology

The dust samples were collected in households in the Oslo area, Norway, during August 2015.

The selection of houses were based on a set of criteria: i) to be representative of average Norwegian households, and ii) to cover families with children up to high school age (i.e. 0-15 years of age). According to Statistics Norway (ssb.no), at least 50% of all households in Norway are single-unit dwellings and 72% of the households are located in buildings with four or less household units (e.g., single houses, terrace houses, etc). In addition, most of the households in Norway are located in densely populated areas. Based on these statistics, we selected single houses, paired houses and terrace houses located in the Oslo area for this study.

We hypothesized that the major contributions to PFASs in homes are consumer products and to a lesser degree building materials. As the lifestyle of families with children might generate a high number of consumer products, and children might be especially exposed to PFASs in house dust, we focused this study on households consisting of families with children up to high school age (i.e. 0-15 years old).

In total, house dust samples were collected from six households. In each household, six separate rooms were sampled; entrance, kitchen, living room, bathroom, children’s bedroom, and parents’ bedroom. This resulted in a total number of 36 samples. An averaged (composite) dust sample was collected in each room, covering all the available exposed horizontal surfaces in the room such as floors, bureaus, bookshelves etc. Collection of dust from all exposed horizontal areas in the rooms was considered the most correct sampling strategy when evaluating exposure and within-house variability as recent studies indicated that averaging dust across a room i) results in stronger relationships to other indoor matrices such as air, and ii) prevents influence of confounding factors and contaminants within the room. Using spot sampling in a specific part of the room might under- or overestimate the variability between rooms. Moreover, toddlers and young children tend to explore all parts of a room.

The participants were asked to clean normally until one week before sampling and then not to vacuum clean or wet clean the floors and the horizontal surfaces in the rooms during the last week before sampling so that all samples would reflect an accumulation time of about one week.

The dust samples were collected on a cellulose filter using an industrial vacuum cleaner (Nilfisk GM 80P) equipped with a special forensic nozzle with a one-way filter housing (KTM AB, Bålsta, Sweden) placed in the front of the vacuum cleaner tube (Bornehag et al., 2005; Huber et al., 2011) (Figure 1). After sampling a lid was put on the filter housing, and the whole sampling compartment was wrapped in double layers of alumina foil, placed in two sealed plastic bags and stored at -20˚C until sample preparation.

After sampling, the sampled area in each room was measured by hand (Table A1).

Field blanks were continuously taken: a filter was transported together with the exposed filters on each sampling occasion (i.e. one per day, n=4 in total). Each filter was opened and inserted into the nozzle once, then repacked in double layer of alumina foil, two plastic bags and stored in freezer next to exposed samples until sample preparation. The field blanks underwent the same analytical procedure as the dust samples.

Figure 1. Sampling equipment for house dust in this study.

3 Analytical methodology

The filter housings were weighed before and after sampling in order to measure the total amount of collected dust. Before the second weighing, larger pieces in the dust (such as hairs, food pieces, stones etc) were discarded leaving a defined dust sample. The amount of dust was used to obtain levels in ng per g of dust as well as to estimate the dust loading in each room (Table A2).

Each dust sample was split in two or three parts based on the total amount of dust in the sample. In general, all samples with a dust amount of >1 g were split in three while those with less were split in two. In order to assess total extractable organic fluorine (TEOF) from all households, also a few samples with <1 g of dust were split in three. All samples were analysed for anionic and volatile PFASs while samples split in three were additionally analysed for TEOF.

Anionic PFASs

An accurately weighed aliquot of the dust sample (0.2 g) plus one part (half or one third depending on the sample split) of the cellulose filter were placed in polypropylene tubes, spiked with 40 μL of internal standard (0.1 ng/μL ^{13}C-labeled anionic PFASs mixture in methanol), vortexed and extracted with methanol in an ultrasonication bath (3x30 min). The extracts were concentrated using RapidVap to a final volume of 1 ml. The concentrate was cleaned with acidified ENVI-Carb (25 mg). Recovery standard (20 μL, 0.1 ng/μL 3,7-dimethyl PFOA or brPFDA) was added in the last step. Prior to analysis an aliquot of the extract (50 μl) was transferred to an autosampler vial and diluted (1:1) with 2 mM aqueous ammonium acetate.

The anionic PFASs were analyzed according to Hanssen et al. (2013). Shortly, the samples were analysed by ultrahigh pressure liquid chromatography triple-quadruple mass-spectrometry (UHPLC–MS/MS). Analyses were performed on a Thermo Scientific quaternary Accela 1250 pump with a PAL Sample Manager coupled to a Thermo Scientific Vantage MS/MS (Vantage TSQ) (all by Thermo Fisher Scientific Inc., Waltham, MA, USA). Ionization was conducted in the negative electrospray ionization mode (ESI-). Quantification was conducted using LCQuan software from Thermo Scientific (Version 2.8) (Thermo Fisher Scientific Inc., Waltham, MA, USA).

Targeted anionic PFASs were: FOSA, PFHxA, PFHpA, PFOA, PFNA, PFDA, PFUnDA, PFDoDA, PFTrDA, PFTeDA, PFBS, PFHxS, sum PFOS (branched and linear), 4:2 Fluorotelomer sulfonic acid (FTSA), 6:2 FTSA, and 8:2 FTSA (full names are given in Table 1).

Volatile/neutral PFASs

An accurately weighed aliquot of the dust sample (0.2 g) plus one part (half or one third depending on the sample split) of the cellulose filter were placed in polypropylene tubes, spiked with 40 μL of internal standard (2.5 ng/μL ^{13}C-labeled FTOH in ethyl acetate), vortexed and extracted with ethyl acetate in an ultrasonication bath (3x30 min). The extracts were concentrated using RapidVap to a final volume of 1 ml. The concentrate was cleaned with ENVI-Carb (25 mg). Recovery standard (20 μL, 0.1 ng/μL 7:1 FTOH) was added in the last step.

The volatile PFASs were analyzed according to Blom and Hanssen (2015). Shortly, the samples were analysed using gas chromatography mass-spectrometry (GC-MS) with positive chemical ionization (PCI) in selected ion monitoring (SIM) mode. Analyses were performed on an Agilent 7890A GC with split/splitless injector coupled to a 5975C MSD (Agilent, Böblingen, Germany). Methane was used as reagent gas in positive chemical ionization (PCI) mode for quantification.

Targeted volatile PFASs were: 4:2 Fluorotelomer alcohol (FTOH), 6:2 FTOH, 8:2 FTOH, and 10:2 FTOH.

Total extractable organic fluorine (TEOF)

The extraction, clean-up and analytical methods for TEOF were based on, although slightly modified, previously published literature (Miyake et al., 2007; Yeung et al., 2013). In short, an accurately weighed aliquot of the dust sample (0.5 g) plus one third of the cellulose filter were placed in polypropylene tubes, vortexed and extracted with methanol in an ultrasonication bath (3x30 min). The extracts were concentrated using RapidVap to a final volume of 1 ml. The concentrate was cleaned with ENVI-Carb columns (100 mg), and in order to remove inorganic fluoride further pre-cleaned using Oasis® WAX columns (150 mg), eluted with methanol and 0.1% NH_4OH/methanol.

Levels of TEOF were measured using a total organofluorine combustion ion chromatography (TOF-CIC) system, which consists of an automated combustion unit (Auto Quick Furnace, AQF-100; Dia Instruments Co., Ltd.), a gas absorption unit (GA-100; Dia Instruments Co., Ltd.), and an ion chromatography system (ICS-2100; Dionex Corp., Sunnyvale, CA). The sample extract (0.1 mL) was introduced on a ceramic boat and placed into a furnace at 900-1000°C for combustion, during which, all organofluorine is converted into hydrogen fluoride (HF); the HF is then absorbed into a 0.2 mmol/L NaOH solution. The fluoride concentration in the solution was analyzed using ion chromatography. Sodium fluoride and methanesulfonic acid (99% purity; Sigma-Aldrich) were used as standard and internal standard for quantification, respectively. A five-point calibration curve at 4, 10, 20, 50, 100, and 200 µg/L standards was prepared, and exhibited good linearity with $r^2 > 0.9999$. Quantification was based on the area count of the external standards that bracketed the concentrations found in the samples. Methanesulfonic acid was present in the absorption solution as an internal standard to correct for any volume changes during the combustion and absorption processes. All solutions were prepared in Milli-Q water with a fluoride concentration <0.025 µg/L. Fluoride concentration in the MeOH was below 4 µg/L (LOQ).

Table 1: Abbreviations and full names of the targeted PFASs in this study (according to Buck, 2011).

Abbreviation	Full name	CAS number
Anionic PFASs		
FOSA	Perfluorooctane sulfonamide	754-91-6
PFHxA	Perfluorohexanoic acid	307-24-4
PFHpA	Perfluoroheptanoic acid	375-85-9
PFOA	Perfluorooctanoic acid	335-67-1
PFNA	Perfluorononanoic acid	375-95-1
PFDA	Perfluorodecanoic acid	335-76-2
PFUnDA	Perfluoroundecanoic acid	2058-94-8
PFDoDA	Perfluorododecanoic acid	307-55-1
PFTrDA	Perfluorotridecanoic acid	72629-94-8
PFTeDA	Perfluorotetradecanoic acid	376-06-7
PFBS	Perfluorobutane sulfonic acid	375-73-5
PFHxS	Perfluorohexane sulfonic acid	355-46-4
PFOS	Perfluorooctane sulfonic acid	1763-23-1
4:2 FTSA	4:2 fluorotelomer sulfonic acid	757124-72-4
6:2 FTSA	6:2 fluorotelomer sulfonic acid	27619-97-2
8:2 FTSA	8:2 fluorotelomer sulfonic acid	39108-34-4
Volatile PFASs		
4:2 FTOH	4:2 fluorotelomer alcohol	2043-47-2
6:2 FTOH	6:2 fluorotelomer alcohol	647-42-7
8:2 FTOH	8:2 fluorotelomer alcohol	678-39-7
10:2 FTOH	10:2 fluorotelomer alcohol	865-86-1

4 Quality assurance/Quality control

One field blank was collected and analysed for every ninth dust samples in order to control possible contamination during sampling, transport, storage and analysis. Field blanks consisted of cellulose filters that were transported and stored together with the exposed samples and analysed in parallel with the real samples (i.e. split in three parts, one for each analysis). The concentrations in the field blanks were, in general, below 5% of the amount in the real samples. This suggests no or minor contamination in the samples and a no blank correction was therefore done.

The uncertainty of the chemical analysis is governed by loss during extraction and clean-up, interference from other compounds, trueness of analytical standards, instrumental parameters, and contamination. NILU follows the normal approach to estimate and quantify these factors by participating in laboratory intercalibrations. Based on the results of intercalibrations, the uncertainty for PFAS is expected to be in the range of 20 to 40%.

5 Results

A suite of 20 targeted PFASs were analysed in 36 samples. The concentrations of the individual PFASs in the house dust from each room are presented in Table 2 (ng/g dust) and Table 3 (ng/m^2). The results for between- and within-house variability are presented separately for anionic and volatile PFASs as both the sources and the migration pathways from sources to house dust may differ for the two groups.

None of the PFASs was detected in 100% of the samples. Four compounds were detected in ~90% of the samples; PFHxA, PFHpA, PFOA, and PFDA. Eight compounds were below the analytical limit of detection (LOD) in more than 50% of the samples; PFOS, FOSA, PFHxS, PFTrDA, PFTeDA, 4:2 FTSA, 4:2 FTOH and 6:2 FTOH. The other eight compounds were detected in 30-60% of the samples; PFBS, PFNA, PFUnDA, PFDoDA, 6:2 FTSA, 8:2 FTSA, 8:2 FTOH, 10:2 FTOH.

For the purposes of further calculations and statistical evaluation, concentrations below LOD were substituted with half the detection limit for the specific PFASs.

The predominant PFASs were the anionic PFHxA, PFOA, PFNA, and 8:2 FTSA together with the volatile PFASs 6:2-10:2 FTOH (Table 2-3, Figure 2) with concentrations ranging between <LOD and 43 ng/g for the anionic PFASs and between 3 and 68 ng/g for the volatile PFASs.

The PFASs concentrations measured in this study are lower than most of the previously published concentrations from households in different countries (Harrad et al., 2010; Goosey and Harrad, 2011). The average concentrations of individual PFASs in this study are also lower than those measured in Norwegian house dust in 2007/08 (Huber et al., 2011) (Figure 3).

Table 2: Measured concentrations of targeted PFASs in house dust (ng/g). Concentrations below LOD are designated with "<" and the respective LOD concentration.

		FOSA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnDA	PFDoDA	PFTrDA	PFTeDA	PFBS	PFHxS	PFOS	4:2 FTSA	6:2 FTSA	8:2 FTSA	4:2 FTOH	6:2 FTOH	8:2 FTOH	10:2 FTOH
A	Entrance	<0.20	8.79	1.45	5.81	10.5	2.86	3.07	1.66	0.77	<0.05	0.42	<0.05	<0.20	<0.10	0.64	2.12	<5.7	<7.8	<9.0	12.2
	Kitchen	<0.20	9.61	1.43	7.02	9.36	2.77	2.17	<0.05	<0.05	0.90	1.69	<0.05	<0.20	<0.10	0.98	2.52	<5.7	<7.8	<9.0	<10.0
	Living room	<0.20	11.7	2.23	12.1	19.9	5.78	6.81	2.75	1.74	1.31	0.69	<0.05	0.28	<0.10	0.12	2.94	<5.7	66.8	<9.0	<10.0
	Bathroom	<0.20	11.4	1.51	5.65	4.64	2.57	1.54	<0.05	<0.05	<0.05	<0.05	<0.05	<0.20	<0.10	<0.05	<0.10	<5.7	<7.8	<9.0	<10.0
	Bedroom Children	<0.20	15.7	1.48	6.41	7.31	2.64	1.42	1.26	<0.05	<0.05	<0.05	<0.05	<0.20	<0.10	<0.05	3.12	<5.7	<7.8	<9.0	<10.0
	Bedroom Parents	<0.20	14.0	1.07	6.45	20.4	3.60	4.93	1.85	0.84	0.93	<0.05	<0.05	<0.20	<0.10	<0.05	2.08	<5.7	<7.8	<9.0	<10.0
B	Entrance	<0.20	6.42	1.06	12.7	7.12	4.75	2.24	2.28	<0.05	0.95	0.54	<0.05	3.05	<0.10	1.09	43.7	<5.7	<7.8	9.7	11.8
	Kitchen	<0.20	<0.05	0.78	8.51	8.06	3.18	2.09	<0.05	<0.05	0.61	<0.05	<0.05	0.30	<0.10	<0.05	13.6	<5.7	<7.8	11.7	<10.0
	Living room	<0.20	9.15	1.73	12.0	13.5	4.29	3.32	2.53	0.50	1.23	0.53	<0.05	1.35	<0.10	0.77	25.32	<5.7	<7.8	9.1	15.1
	Bathroom	<0.20	6.71	1.62	19.4	8.25	2.97	1.24	0.47	<0.05	<0.05	0.76	<0.05	1.18	<0.10	9.17	<0.10	<5.7	<7.8	19.0	21.4
	Bedroom Children	<0.20	14.4	1.22	9.04	5.93	2.51	2.11	1.01	0.15	0.55	0.53	<0.05	2.97	<0.10	<0.05	12.6	<5.7	<7.8	12.8	<10.0
	Bedroom Parents	<0.20	10.5	1.47	42.7	13.9	4.25	2.02	1.15	<0.05	0.42	0.56	<0.05	1.17	<0.10	0.36	18.6	<5.7	11.7	12.0	<10.0
C	Entrance	<0.20	4.73	1.10	4.23	0.78	1.52	0.29	0.61	<0.05	<0.05	0.06	<0.05	<0.20	<0.10	0.16	1.61	<5.7	<7.8	<9.0	<10.0
	Kitchen	<0.20	<0.05	<0.05	2.40	0.57	<0.05	<0.05	0.21	<0.05	<0.05	1.96	<0.05	<0.20	<0.10	<0.05	<0.10	<5.7	<7.8	<9.0	<10.0
	Living room	<0.20	12.3	2.06	8.65	3.31	2.39	1.15	1.15	<0.05	<0.05	<0.05	<0.05	<0.20	<0.10	0.74	3.51	<5.7	<7.8	<9.0	<10.0
	Bathroom	<0.20	5.33	0.47	3.82	<0.05	1.13	0.23	<0.05	<0.05	<0.05	0.10	<0.05	<0.20	<0.10	<0.05	1.77	<5.7	<7.8	<9.0	<10.0
	Bedroom Children	<0.20	40.2	1.95	11.7	<0.05	6.68	3.34	2.97	<0.05	<0.05	3.31	<0.05	6.58	<0.10	0.96	39.9	<5.7	<7.8	15.6	14.6

		FOSA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnDA	PFDoDA	PFTrDA	PFTeDA	PFBS	PFHxS	PFOS	4:2 FTSA	6:2 FTSA	8:2 FTSA	4:2 FTOH	6:2 FTOH	8:2 FTOH	10:2 FTOH
	Bedroom Parents	<0.20	18.0	8.86	10.7	20.9	1.16	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.20	<0.10	<0.05	<0.10	<5.7	<7.8	11.9	18.5
D	Entrance	<0.20	2.23	0.28	1.62	0.62	0.53	<0.05	<0.05	<0.05	<0.05	0.12	<0.05	<0.20	<0.10	<0.05	<0.10	<5.7	22.4	14.6	13.3
	Kitchen	<0.20	5.49	<0.05	2.67	0.38	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.20	<0.10	<0.05	<0.10	<5.7	<7.8	<9.0	30.4
	Living room	<0.20	9.94	0.75	4.31	<0.05	<0.05	<0.05	0.75	<0.05	<0.05	<0.05	<0.05	<0.20	<0.10	<0.05	<0.10	<5.7	66.4	68.4	40.5
	Bathroom	<0.20	8.85	1.17	3.25	<0.05	1.32	0.45	0.46	<0.05	<0.05	<0.05	<0.05	<0.20	<0.10	<0.05	0.76	<5.7	20.3	13.9	27.8
	Bedroom Children	<0.20	19.0	1.13	3.21	0.87	1.75	<0.05	0.31	<0.05	<0.05	0.13	<0.05	<0.20	<0.10	<0.05	<0.10	<5.7	<7.8	9.12	12.3
	Bedroom Parents	<0.20	7.09	0.98	4.85	<0.05	1.82	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.20	<0.10	0.36	<0.10	<5.7	<7.8	11.0	16.9
E	Entrance	<0.20	20.7	0.63	5.32	<0.05	3.01	<0.05	1.32	<0.05	0.16	1.83	<0.05	0.51	<0.10	1.17	41.5	<5.7	<7.8	10.8	12.0
	Kitchen	<0.20	14.3	0.68	2.74	<0.05	1.01	0.13	0.16	<0.05	<0.05	<0.05	<0.05	<0.20	<0.10	<0.05	6.80	<5.7	<7.8	<9.0	<10.0
	Living room	<0.20	5.50	0.67	3.49	0.89	1.30	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.20	<0.10	0.09	5.36	<5.7	<7.8	9.79	<10.0
	Bathroom	<0.20	<0.05	<0.05	2.81	<0.05	0.61	<0.05	<0.05	<0.05	<0.05	0.54	<0.05	<0.20	<0.10	<0.05	4.88	<5.7	<7.8	9.07	12.5
	Bedroom Children	<0.20	6.87	0.55	2.43	0.73	1.26	0.32	0.21	<0.05	<0.05	<0.05	<0.05	<0.20	<0.10	0.22	6.49	<5.7	<7.8	<9.0	19.0
	Bedroom Parents	<0.20	5.67	0.54	2.48	0.66	1.27	0.32	<0.05	<0.05	<0.05	<0.05	<0.05	<0.20	<0.10	0.34	7.88	<5.7	<7.8	<9.0	11.3
F	Entrance	<0.20	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.20	<0.10	<0.05	<0.10	<5.7	9.12	<9.0	<10.0
	Kitchen	<0.20	20.2	<0.05	3.86	<0.05	1.39	0.15	0.13	0.07	0.21	2.61	<0.05	<0.20	<0.10	0.21	9.37	<5.7	19.1	15.6	10.8
	Living room	<0.20	32.9	1.61	6.72	0.61	2.27	0.13	0.63	<0.05	<0.05	1.11	<0.05	<0.20	<0.10	0.60	12.3	<5.7	21.5	<9.0	<10.0
	Bathroom	<0.20	7.50	0.50	3.90	0.72	1.71	0.54	0.88	0.07	<0.05	0.57	<0.05	0.60	<0.10	<0.05	9.59	<5.7	3.90	<9.0	<10.0
	Bedroom Children	<0.20	24.4	1.68	11.0	2.90	4.85	1.68	2.70	<0.05	0.95	0.99	<0.05	2.95	<0.10	2.02	19.7	<5.7	5.81	11.0	<10.0
	Bedroom Parents	<0.20	9.43	0.55	7.18	<0.05	2.67	<0.05	0.72	<0.05	<0.05	0.10	<0.05	<0.20	<0.10	0.44	<0.10	<5.7	8.58	15.7	17.0

Table 3: Concentrations of targeted PFASs in house dust based on surface area (ng/m^2). Concentrations below LOD are designated with "<" and the respective LOD concentration.

		FOSA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnDA	PFDoDA	PFTrDA	PFTeDA	PFBS	PFHxS	PFOS	4:2 FTSA	6:2 FTSA	8:2 FTSA	4:2 FTOH	6:2 FTOH	8:2 FTOH	10:2 FTOH
A	Entrance	<0.03	1.51	0.25	1.00	1.80	0.49	0.53	0.29	0.13	<0.01	0.07	<0.01	<0.03	<0.02	0.11	0.36	<0.98	<1.34	<1.54	2.08
	Kitchen	<0.02	0.82	0.12	0.60	0.80	0.24	0.19	<0.01	<0.01	0.08	0.15	<0.01	<0.02	<0.01	0.08	0.22	<0.49	<0.67	<0.77	<0.85
	Living room	<0.02	1.05	0.20	1.09	1.78	0.52	0.61	0.25	0.16	0.12	0.06	<0.01	0.03	<0.01	0.01	0.26	<0.51	5.99	<0.81	<0.90
	Bathroom	<0.04	2.42	0.32	1.20	0.98	0.54	0.33	<0.01	<0.01	<0.01	<0.01	<0.01	<0.04	<0.02	<0.01	<0.02	<1.21	<1.65	<1.90	<2.10
	Bedroom Children	<0.03	2.64	0.25	1.08	1.23	0.44	0.24	0.21	<0.01	<0.01	<0.01	<0.01	<0.03	<0.02	<0.01	0.52	<0.96	<1.31	<1.51	<1.68
	Bedroom Parents	<0.16	11.4	0.88	5.26	16.63	2.93	4.02	1.50	0.68	0.76	<0.04	<0.04	<0.16	<0.08	<0.04	1.69	<4.66	<6.34	<7.33	<8.14
B	Entrance	<0.43	13.7	2.26	26.9	15.2	10.1	4.77	4.86	<0.11	2.02	1.15	<0.11	6.50	<0.21	2.32	92.9	<12.2	<16.6	20.7	25.2
	Kitchen	<0.03	<0.01	0.10	1.13	1.07	0.42	0.28	<0.01	<0.01	0.08	<0.01	<0.01	0.04	<0.01	<0.01	1.81	<0.76	<1.04	1.56	<1.33
	Living room	<0.02	0.81	0.15	1.06	1.20	0.38	0.29	0.22	0.04	0.11	0.05	<0.01	0.12	<0.01	0.07	2.24	<0.51	<0.69	0.80	1.34
	Bathroom	<0.08	2.80	0.68	8.07	3.44	1.24	0.52	0.20	<0.02	<0.02	0.32	<0.02	0.49	<0.04	3.83	<0.04	<2.39	<3.25	7.94	8.92
	Bedroom Children	<0.08	5.59	0.47	3.50	2.30	0.97	0.82	0.39	0.06	0.21	0.21	<0.02	1.15	<0.04	<0.02	4.88	<2.22	<1.41	4.97	<3.83
	Bedroom Parents	<0.04	1.88	0.26	7.62	2.48	0.76	0.36	0.21	<0.01	0.08	0.10	<0.01	0.21	<0.02	0.07	3.32	<1.02	2.09	2.15	<1.79
C	Entrance	<0.12	2.93	0.68	2.62	0.48	0.94	0.18	0.38	<0.03	<0.03	0.04	<0.03	<0.12	<0.06	0.10	1.00	<3.54	<4.82	<5.57	<6.19
	Kitchen	<0.03	<0.01	<0.01	0.35	0.08	<0.01	<0.01	0.03	<0.01	<0.01	0.28	<0.01	<0.03	<0.01	<0.01	<0.01	<0.82	<1.12	<1.30	<1.44
	Living room	<0.03	1.59	0.27	1.12	0.43	0.31	0.15	0.15	<0.01	<0.01	<0.01	<0.01	<0.03	<0.01	0.10	0.45	<0.74	<1.07	<1.16	<1.29
	Bathroom	<0.04	0.99	0.09	0.71	<0.01	0.21	0.04	<0.01	<0.01	<0.01	0.02	<0.01	<0.04	<0.02	<0.01	0.33	<1.06	<1.45	<1.67	<1.86
	Bedroom Children	<0.03	6.07	0.29	1.77	<0.01	1.01	0.50	0.45	<0.01	<0.01	0.50	<0.01	0.99	<0.02	0.15	6.03	<0.86	<1.18	2.35	2.20
	Bedroom Parents	<0.03	2.25	1.10	1.34	2.61	0.14	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.03	<0.01	<0.01	<0.01	<0.71	<0.97	1.48	2.31

		FOSA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnDA	PFDoDA	PFTrDA	PFTeDA	PFBS	PFHxS	PFOS	4:2 FTSA	6:2 FTSA	8:2 FTSA	4:2 FTOH	6:2 FTOH	8:2 FTOH	10:2 FTOH
D	Entrance	<0.05	0.55	0.07	0.40	0.15	0.13	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	<0.05	<0.03	<0.01	<0.03	<1.42	5.57	3.63	3.13
	Kitchen	<0.01	0.26	<0.01	0.13	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.27	<0.37	<0.43	1.45
	Living room	<0.02	1.08	0.08	0.47	<0.01	<0.01	<0.01	0.08	<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01	<0.62	7.23	7.45	4.42
	Bathroom	<0.02	0.87	0.11	0.32	<0.01	0.13	0.04	0.05	<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	0.07	<0.56	1.99	1.36	2.72
	Bedroom Children	<0.03	2.69	0.16	0.46	0.12	0.25	<0.01	0.05	<0.01	<0.01	0.02	<0.01	<0.03	<0.01	<0.01	<0.01	<0.81	<1.11	1.29	1.75
	Bedroom Parents	<0.02	0.82	0.11	0.56	<0.01	0.21	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	0.04	<0.01	<0.66	<0.90	1.26	1.94
E	Entrance	<0.04	4.11	0.13	1.06	<0.01	0.60	<0.01	0.26	<0.01	0.03	0.36	<0.01	0.10	<0.02	0.23	8.23	<1.13	<1.55	2.14	2.39
	Kitchen	<0.04	3.03	0.15	0.58	<0.01	0.21	0.03	0.03	<0.01	<0.01	<0.01	<0.01	<0.04	<0.02	<0.01	1.44	<1.21	<1.65	<1.91	<2.12
	Living room	<0.02	0.66	0.08	0.42	0.11	0.16	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	0.01	0.65	<0.69	<0.94	1.18	<1.20
	Bathroom	<0.04	<0.01	<0.01	0.50	<0.01	0.11	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.04	<0.02	<0.01	0.87	<1.02	<1.39	1.62	2.23
	Bedroom Children	<0.13	4.55	0.37	1.61	0.49	0.84	0.21	0.14	<0.03	<0.03	<0.03	<0.03	<0.13	<0.07	0.15	4.30	<3.79	<5.16	<5.96	12.6
	Bedroom Parents	<0.26	7.42	0.71	3.25	0.86	1.66	0.41	<0.07	<0.07	<0.07	<0.07	<0.07	<0.26	<0.13	0.45	10.3	<7.48	<10.2	<11.8	14.8
F	Entrance	<0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.04	<0.02	<0.01	<0.02	<1.08	<1.72	<1.69	<1.88
	Kitchen	<0.04	3.61	<0.01	0.69	<0.01	0.25	0.03	0.02	0.01	0.04	0.47	<0.01	<0.04	<0.02	0.04	1.67	<1.02	<3.41	2.78	1.93
	Living room	<0.01	1.76	0.09	0.36	0.03	0.12	<0.01	0.03	<0.01	<0.01	0.06	<0.01	<0.01	<0.01	0.03	0.66	<0.31	<1.15	<0.48	<0.54
	Bathroom	<0.02	0.74	0.05	0.39	0.07	0.17	0.05	0.09	<0.01	<0.01	0.06	<0.01	0.06	<0.01	<0.01	0.95	<0.56	<0.77	<0.89	<0.99
	Bedroom Children	<0.05	5.98	0.41	2.69	0.71	1.19	0.41	0.66	0.01	0.23	0.24	<0.01	0.72	<0.03	0.50	4.84	<1.40	<1.43	2.70	2.46
	Bedroom Parents	<0.02	0.98	0.06	0.75	<0.01	0.28	<0.01	0.08	<0.01	<0.01	0.01	<0.01	<0.02	<0.01	0.05	0.01	<0.56	<0.89	1.64	1.77

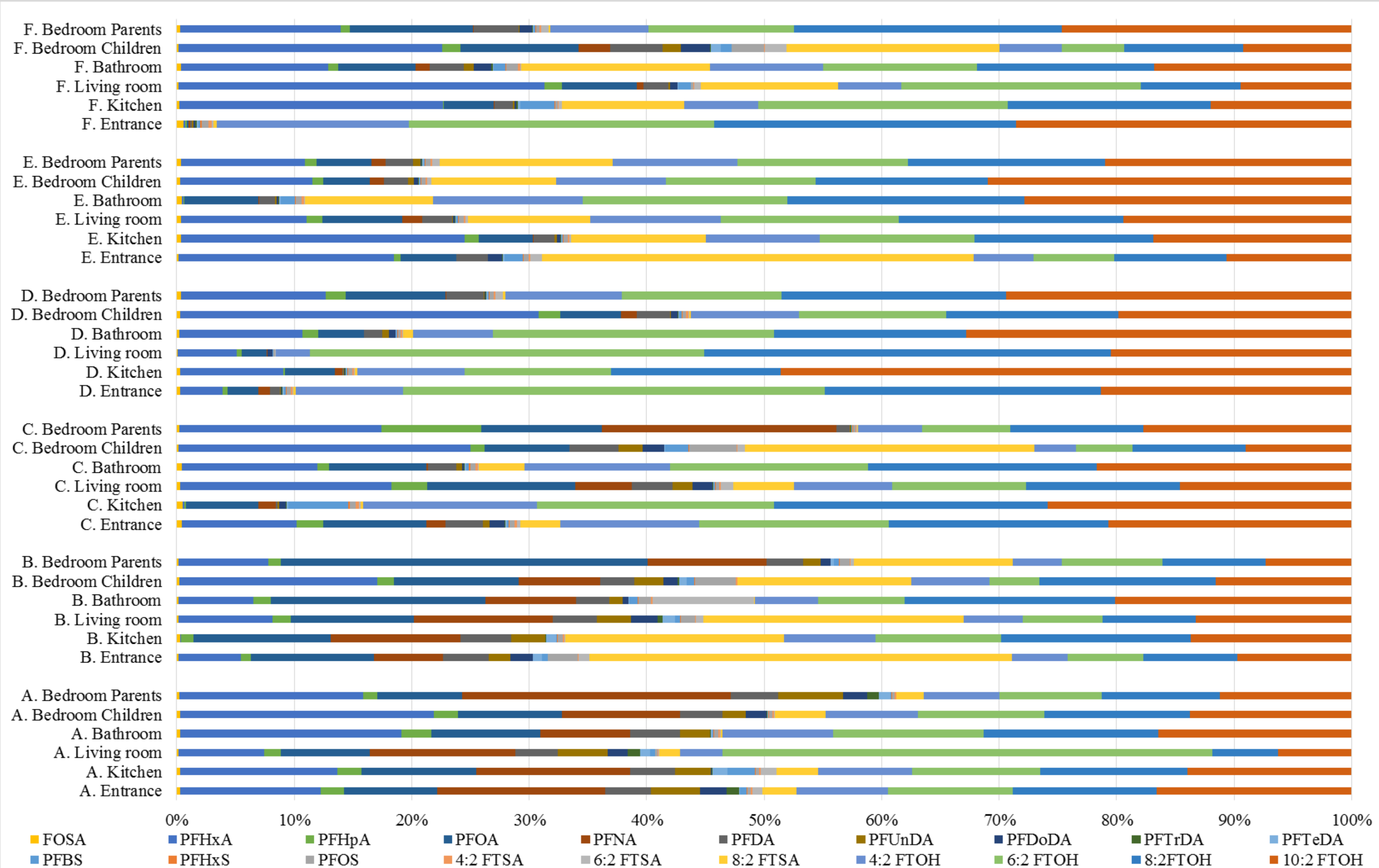

Figure 2. Composition of the targeted PFASs in house dust from each sampled room and household.

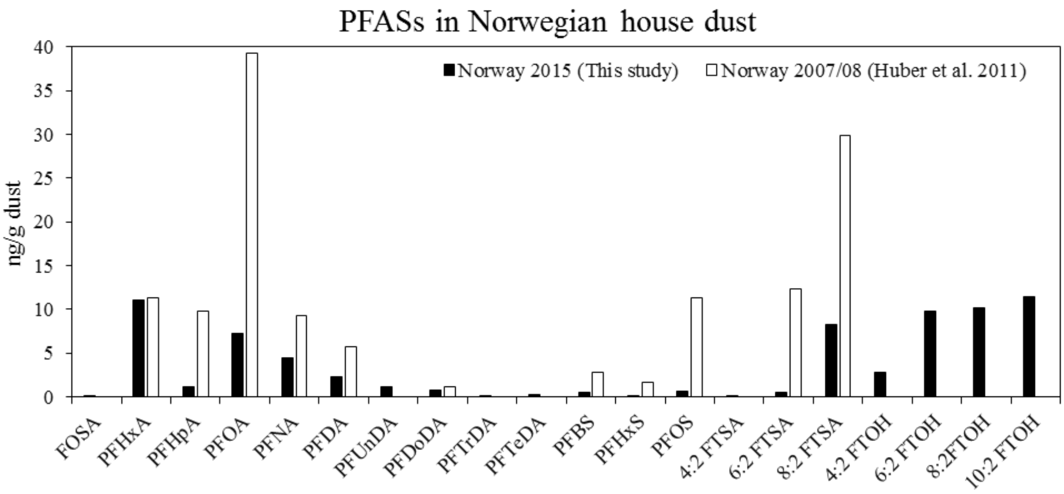

Figure 3. Average house dust concentrations for individual targeted PFASs in Norway in 2015 (this study) and in 2007/08 (Huber, 2011).

Within- and between-house variability

The variability of concentrations within and between households are presented in Table 4-5 and Figure 4-6 for sum anionic PFASs (ng/g dust) and sum volatile PFASs (ng/g dust) respectively. The results are presented separately for the two groups as both their sources as well as migration pathways to the dust are expected to differ. Significant differences between houses ($p<0.05$, t-test) were seen for both anionic and volatile PFASs. Within-houses, the anionic PFASs tend to be consistently higher in the bedrooms and living rooms than the other rooms. This difference was significant when bedrooms and living rooms were compared to bathrooms but not to kitchen and entrances. For the volatile PFASs no consistent trend of within-house variability was seen.

Table 4. House dust concentrations of sum anionic PFASs (ng/g) in individual rooms and the average of all rooms in each sampled household. Concentrations below LOD are substituted with half the detection limit for the specific PFASs

	Entrance	**Kitchen**	**Living room**	**Bathroom**	**Bedroom Children**	**Bedroom Parents**	**Average all rooms**
Household A	36.3	36.3	65.6	*27.8*	36.6	54.4	42.8
Household B	42.4	23.8	51.1	51.9	40.6	78.7	48.1
Household C	13.8	*5.6*	*32.1*	*11.5*	78.0	*60.1*	33.5
Household D	*5.8*	*9.0*	*16.2*	*15.9*	*26.7*	*15.5*	*14.9*
Household E	34.9	*19.4*	12.4	*4.4*	12.9	11.6	16.0
Household F	0.5*	29.2	46.9	17.2	56.2	*21.5*	28.6

*All of the anionic PFASs <LOD in this sample.
Italic data means that more than 60% of the anionic PFASs are <LOD.

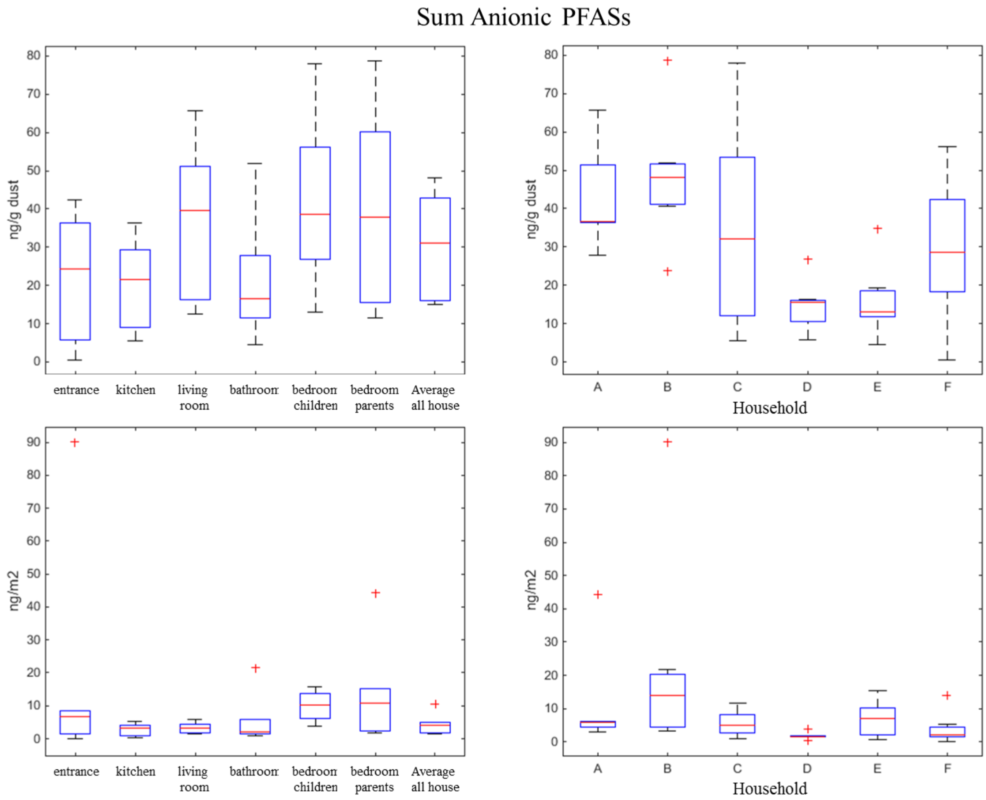

Figure 4. Boxplots of sum anionic PFASs in house dust in specific rooms (left) and individual households (right), in ng/g dust and ng/m^2 respectively. Whiskers represent 5 and 95 percentiles, the boxes represents 25 and 75 percentile, and the red lines represent the median.

Table 5. House dust concentrations of volatile PFASs (ng/g dust) in individual rooms and the average of all rooms in each sampled household. Concentrations below LOD are designated with “<” and the respective LOD concentration.

	Entrance	Kitchen	Living room	Bathroom	Bedroom Children	Bedroom Parents	Average all rooms
Household A	*23.4*	*<16.3*	*79.2*	*<16.3*	*<16.3*	*<16.3*	*27.9*
Household B	28.3	*23.5*	31.0	47.2	29.2	31.6	31.8
Household C	*<16.3*	*<16.3*	*<16.3*	*<16.3*	36.9	37.1	23.2
Household D	53.2	*41.6*	178	64.7	28.2	34.6	66.8
Household E	*29.6*	*<16.3*	*21.5*	28.3	*30.2*	*22.5*	24.7
Household F	*21.5*	48.3	*33.9*	<16.3	*24.7*	44.1	31.5

Italic data means that more than 60% of the anionic PFASs are <LOD.

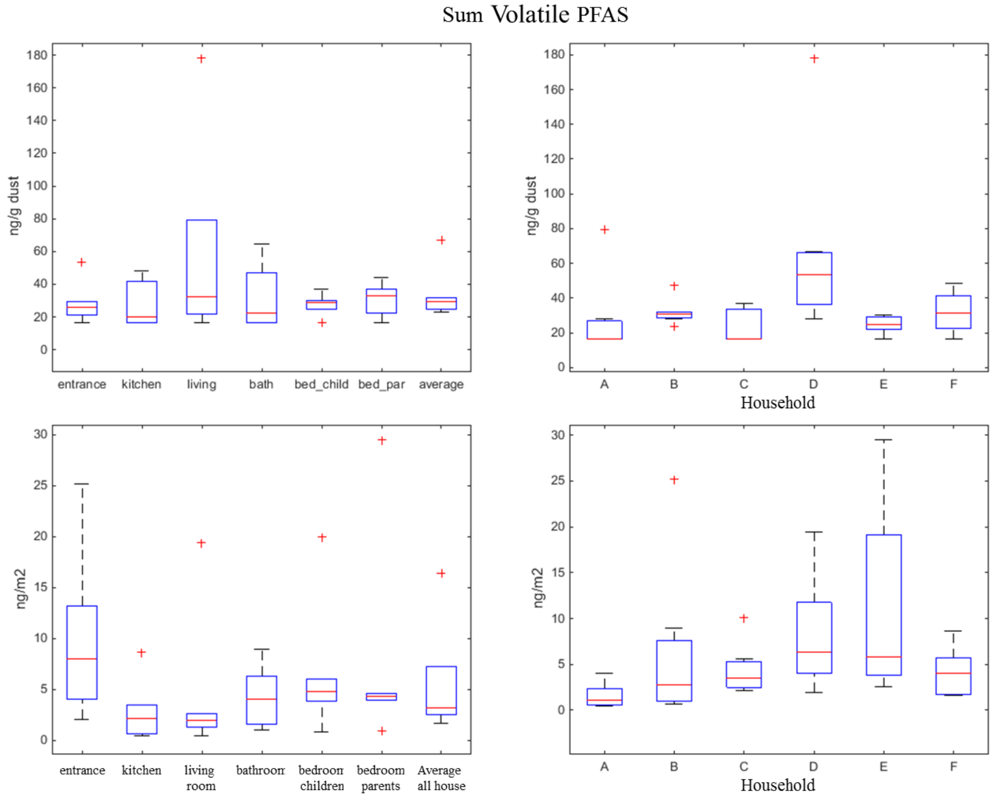

Figure 5. Boxplots of sum volatile PFASs in house dust in specific rooms (left) and individual households (right), in ng/g dust and ng/m^2 respectively. Whiskers represent 5 and 95 percentiles, the boxes represents 25 and 75 percentile, and the red lines represent the median.

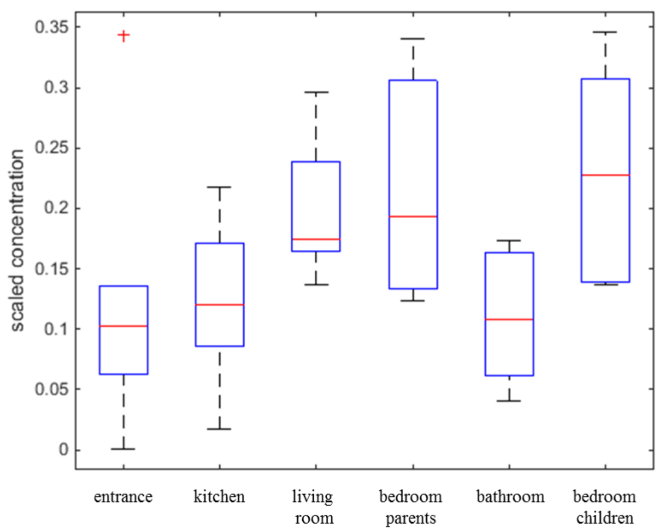

Figure 6. Within-house variability of the predominant PFASs (PFHxA, PFOA, PFNA, 8:2 FTSA, 6:2-10:2 FTOH) based on the contribution of each room to the total concentration in each household.

Total extractable organic fluorine (TEOF)

The TEOF content in house dust was analysed in a selection of rooms based on the availability of dust. This is, to our knowledge, the first report presenting results for TEOF in house dust. The TEOF concentrations in the dust samples ranged between 15 and 96 ng F/g dust, details are presented in Table 6. The results for TEOF show significant differences between the houses.

The amount of TEOF in each room was compared to the total amount of targeted anionic PFASs (sum anionic PFASs) based on their fluorine content (Figure 7). The volatile PFASs were not included in the comparison as they are lost during the sample preparation for TEOF. The contribution of sum of anionic PFASs to the TEOF were found to range between 10 and >100%. This comparison might be biased by the use of different extraction and clean-up methodologies.

Table 6. TEOF concentrations (ng F/g) in a selection of rooms.

	Entrance	**Kitchen**	**Living room**	**Bathroom**	**Bedroom children**	**Bedroom parents**
Household A			42.8		43.6	31.6
Household B		41.3		32.3	88.7	30.2
Household D	15.4		*		14.9	
Household E	18.5				16.7	95.6
Household F	72.2	51.0			16.4	

*Results missing.

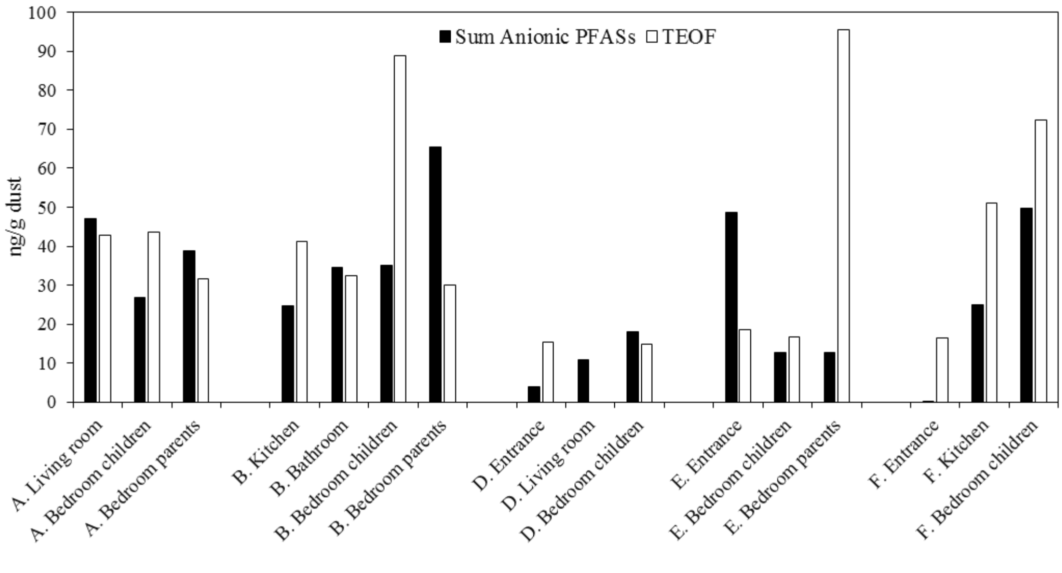

Figure 7. Comparison of amounts (ng/g dust) of sum anionic PFASs (based on fluorine content) and TEOF in individual households and rooms.

6 Conclusion

The purpose of this report was to present sampling methodologies and results of the sampling campaign for PFASs in Norwegian house dust. No evaluation of the data has been carried out.

The obtained results for PFASs in house dust show a significant variability between houses for anionic and volatile PFASs, while the within-house variability was less significant. The volatile PFASs show no within-house variability but the anionic PFASs indicate higher concentrations in bedrooms (children and parents) and living rooms than in bathrooms, kitchen and entrances. The results suggest that factors like building materials and consumer products (e.g., furniture, textiles etc.) affect the levels of PFASs in house dust, but the reason for the findings are not further evaluated in this report.

The levels of all targeted PFASs in this study are lower than those measured in Norwegian households in 2006/07 (Huber et al., 2011).

In this study, the amount of TEOF in house dust was analysed for the first time. The results show similar between-house variability as the targeted PFASs. The anionic PFASs accounted for 10 to 100% of the TEOF, which suggests that non-targeted or unidentified PFASs may exist in some samples.

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APPENDIX A

Sampling and household information

Table A1. Sampled area (m^2) in each room

	Entrance	Kitchen	Living room	Bathroom	Bedroom Children	Bedroom Parents
Household A	5.1	6.4	11.9	2.5	6.2	4.8
Household B	1.5	5.0	5.0	2.9	4.4	5.9
Household C	1.6	3.3	5.1	2.7	2.3	3.2
Household D	4.1	6.1	5.5	3.0	4.4	5.1
Household E	3.1	2.8	3.9	1.9	1.2	1.0
Household F	4.5	4.7	5.3	4.3	3.3	6.3

Table A2. Dust loading (g/m^2) in each room

	Entrance	Kitchen	Living room	Bathroom	Bedroom Children	Bedroom Parents
Household A	0.17	0.09	0.09	0.21	0.17	0.81
Household B	1.79	0.07	0.21	0.24	0.70	0.28
Household C	0.62	0.14	0.13	0.19	0.15	0.13
Household D	0.25	0.05	0.11	0.10	0.14	0.12
Household E	0.20	0.21	0.12	0.18	0.66	1.31
Household F	0.19	0.18	0.05	0.10	0.25	0.10

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Norwegian Environment Agency

ABSTRACT

NILU has, on behalf of the Norwegian Environment Agency, performed sampling and analysis of house dust from Norwegian households. The goal was to study concentration ranges, and variability between- and within-houses of anionic and volatile per- and polyfluorinated alkyl substances (PFASs), including the regulated PFOA, as well as for total extractable organic fluorine (TEOF). The sampling was done in six separate rooms in six different households. The analysis covered a suite of 20 targeted PFASs; ten of these were consistently detected in most samples while the other ten were below detection limit in the major part of the samples. A range of the targeted PFASs were detected in all rooms except in one room in one household in which all PFASs were below detection. The concentrations of individual PFASs as well as the sum of PFASs were lower than a previous study in Norway. The results show significant variability between houses for the anionic and volatile PFASs as well as for TEOF. For anionic PFASs, the results also indicate within-house variability with higher concentrations in dust from bedrooms (children and parents) and living rooms than in dust from bathroom, kitchen and entrances. For the volatile PFASs and TEOF, no significant difference between rooms were found. These results indicate that factors like building materials and consumer products (e.g., furniture, textiles etc.) affect the levels of PFASs in house dust but the reason for the findings are not further evaluated in this report. Anionic PFASs seem to contribute significantly to the TEOF (10-100%) in house dust.

NORWEGIAN TITLE
PFASer i husstøv

KEYWORDS		
Indoor environment	PFC – polyfluorinated compounds	Persistent pollutants

ABSTRACT (in Norwegian)

NILU har på vegne av Miljødirektoratet utført prøvetaking og analyse av støv fra norske hjem/husholdninger. Målet med studien var å se på konsentrasjonsområder samt variasjon av mengden perfluorerte forbindelser (PFASs) innad i hjemmet og mellom forskjellige hjem. Både ioniske og flyktige PFASs ble undersøkt, hvor den regulerte PFASen PFOA var inkludert i analysen, samt totalt ekstraherbart organisk fluor (TEOF). Seks separate rom i seks forskjellige husholdninger var innlemmet i prøvetakingen. Analysepakken bestod av 20 forskjellige PFAS hvor 10 ble påvist i majoriteten av prøvene. De resterende PFAS var under deteksjonsgrensen i en stor del av prøvene. En rekke av de utvalgte PFASene ble påvist i alle rom med unntak av ett rom i et hjem hvor alle PFASene var under deteksjonsgrensen. Mengden av de individuelle PFASene og sumPFASs var lavere sammenlignet med en tidligere utført studie i Norge. Resultatene viste at det var stor variasjon mellom husholdningene for de ioniske og flyktige PFASene og TEOF. Konsentrasjonen av de ioniske PFASene varierte innad i husholdningen med en tendens til høyere konsentrasjoner i soverom (barn og foreldres) og stue sammenlignet med bad, kjøkken og gang. Det var ingen forskjell mellom de forskjellige rommene i husholdningen når det gjaldt mengde flyktige PFASs og TEOF. Disse resultatene indikerer at mulige kilder slik som bygningsmateriale og forbrukerprodukter (f.eks. møbler, tekstiler og liknende) kan påvirke mengden PFASs i husstøv. Denne observasjonen er ikke evaluert i denne rapporten. Ioniske PFASs bidrar betydelig til TEOF (10-100%).

** Classification*	*A*	*Unclassified (can be ordered from NILU)*
	B	*Restricted distribution*
	C	*Classified (not to be distributed)*

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