

11/06 June 2006

FLUORINATED CHEMICALS: UK DIETARY INTAKES

Summary

Composite food group samples from the 2004 Total Diet Study (TDS) were analysed for a range of fluorinated chemicals, including perfluorooctane sulphonate (PFOS) and perfluorooctanoic acid (PFOA). This work was carried out to allow an estimate of dietary intakes of fluorinated chemicals by UK consumers and to obtain an initial indication of whether any specific food groups are significant dietary sources. The results are of low concern regarding human health.

Key Facts

- This work was carried out following an increasing number of reports of PFOS and PFOA being found in the environment, in fish and in other foods.
- PFOS, PFOA and related fluorinated chemicals were analysed in composite samples of food groups from the 2004 TDS.
- PFOS was found at concentrations above the limit of detection in the potatoes, canned vegetables, eggs and sugars & preserves food groups. PFOA was detected only in the potatoes food group. Other fluorinated chemicals were detected only occasionally, although ten different fluorinated compounds were found in the potatoes food group.
- The estimated average adult dietary intakes from the whole diet in 2004 were 0.1 microgram/kg bodyweight/day for PFOS and 0.07 microgram/kg bodyweight/day for PFOA (upper bound figures). The corresponding high level adult dietary intakes were 0.2 and 0.1 microgram/kg bodyweight/day respectively.
- The independent expert Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT) is reviewing the toxicity of PFOS and PFOA, and has received advice from its sister Committees on Mutagenicity (COM) and Carcinogenicity (COC). The COT has not finalised its opinion on establishing Tolerable Daily Intakes for PFOS or PFOA. However, with regards to the results of the survey, it considered that there is considerable uncertainty in intakes, since the majority of food

- groups do not contain PFOS and PFOA at concentrations above limits of detection, and the survey results did not raise any immediate toxicological concerns.

Background

PFOS belongs to a group of fluorinated chemicals often referred to as perfluoroalkyl substances (PFAS). Other chemicals in this group are homologues of PFOS and derivatives such as perfluorooctanesulphonyl fluoride (POSF), amines, amides, carboxylates and perfluorooctane sulphonamide (PFOSA). PFOA includes the anion and salts of perfluorooctanoic acid.

Fluorinated chemicals are widely used in the manufacture of plastics, electronics, textile and consumer material in the apparel, leather, and upholstery industries where they provide soil, oil and water resistance. PFOS salts are a component of fire-fighting foam concentrates and PFOA is primarily used as an emulsifier in industrial applications, for example in the production of fluoropolymers such as polytetrafluoroethylene (PTFE). These chemicals have been imported into but not manufactured in the UK. They are very resistant to both chemical and biological attack and are therefore persistent in the environment. PFOS in particular appears to be ubiquitous, although it does degrade slowly under certain conditions. The Organisation of Economic Co-operation and Development (OECD) has concluded that risk reduction measures are needed for these chemicals,¹ and some have already been put into place in the UK.²

PFOS and PFOA tend to bind to certain proteins rather than bioconcentrate in fat, but they have some potential to bioaccumulate in the food chain. Accordingly, they may be found in the blood and liver rather than the fatty components of foods. There have been relatively few reported occurrences of PFOS and even fewer of PFOA in food. Most of these have been in the blood and liver of fish.³⁻¹⁰ In addition, PFOS has also been detected occasionally in milk and ground beef, and PFOA in bread, apples and beans.¹¹ Both chemicals have been detected in human milk.¹² Other PFAS appear only to have been analysed in the liver of cattle, chicken and pigs in a Japanese study of farm animals in which PFOS and PFOA were also analysed.¹³ The Food Standards Agency is not aware of any estimates of dietary intakes of PFOS or PFOA in other countries, but work is in progress in Germany.¹⁴ The Scientific Panel on Contaminants in the Food Chain of the European Food Safety Authority is also currently finalising its opinion on PFOS and its salts (Question No. EFSA-Q-2004-163).

This work represents the first extensive survey for fluorinated organic chemicals in food in the UK.

Methodology

The Total Diet Study models the typical UK diet, and is described more fully in Food Survey Information Sheet No 38/03.¹⁵ Composite samples of all of the food group sub-samples purchased from the different locations in the UK in 2004 were tested.

Analysis

Samples were analysed by the Central Science Laboratory (CSL) using high pressure liquid chromatography-mass spectrometry following extraction and cleanup using the method of Taniyasu.¹⁶ Full details of the analytical methodology can be found in the contractor's final report for the survey.¹⁷ The compounds measured are listed in Table 1. The inclusion of fluorinated chemicals other than PFOS and PFOA was limited by the availability of internal analytical standards. Analysis of these samples was carried out in conjunction with CSL's participation in the 1st Worldwide Interlaboratory Study on Perfluorinated Compounds in Environmental and Human Samples, through which CSL gained accreditation for the analysis.¹⁸

Results

This report presents the results for PFOS and PFOA (Table 2). Full details of the results of each of the individual PFASs analysed can be found in the contractor's final report for the work.¹⁷ Brand names are not available for this survey as composite samples, each comprising a mixture of different branded foods, were analysed.¹⁹

PFOS was detected at concentrations above the limit of determination in the potatoes, canned vegetables, eggs and sugars & preserves food groups. PFOA was detected only in the potatoes food group. Five of the fluorinated chemicals measured were not detected in any of the food groups, and the others were detected only occasionally. Ten fluorinated compounds were detected in the potatoes food group. The potatoes group comprises not only fresh potatoes (baked, boiled or microwaved, with or without skin) but also prepared and processed products such as instant potato, chips, crisps and other potato snacks, croquettes and hash browns and potato salad. This group will require further study in order to understand the high results.

Tables 3 and 4 show the dietary intakes by consumers of various age groups, estimated using food consumption data from various dietary surveys.²⁰⁻²³

The estimated average dietary intakes of fluorinated chemicals by adults from the whole diet in 2004 were 0.1 microgram/kg bodyweight per day for PFOS and 0.07 microgram/kg bodyweight per day for PFOA.

Interpretation

The independent expert Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT) is reviewing the toxicity of PFOS and PFOA. The sister Committees on Mutagenicity (COM) and Carcinogenicity (COC) have considered these chemicals and submitted their conclusions to the COT. The COT has not finalised its opinion on establishing Tolerable Daily Intakes (TDIs) for PFOS or PFOA. The Committee noted the results of the survey and considered that there is considerable uncertainty in intakes, since the majority of food groups do not contain PFOS or PFOA at concentrations above limits of detection, and the survey results did not raise any immediate toxicological concerns.

Conclusion

This Total Diet Study has provided an initial assessment of dietary exposure. However, because a wide range of foods are included in each group, the contribution from individual samples that might be contaminated at a high level will probably be masked. Consequently, further investigations will be considered for individual foods for which literature reports indicate possible contamination, such as potatoes, fish and offals.

Summary of Units

kg	a kilogram (kg) is one thousand grams (g)
microgram	one millionth of a gram
ng	a nanogram (ng) is one thousand millionth of a gram
ng/kg bw/day	nanograms per kilogram of bodyweight per day; equivalent to parts per million million (parts per trillion) by weight.

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Further Information

Further information on this survey can be obtained from:

Mr Martin Gem

Food Standards Agency

Chemical Safety Division

Aviation House

Room 707C

125 Kingsway

London WC2B 6NH

Tel: +44 (0) 20 7276 8724

Fax: +44 (0) 20 7276 8717

E-mail: martin.gem@foodstandards.gsi.gov.uk

Further copies of this summary report can be obtained from:

Library

Food Standards Agency

Ground Floor

Aviation House

125 Kingsway

London WC2B 6NH

Tel: +44 (0) 20 7276 8281/8182

Fax: +44 (0) 20 7276 8193

E-mail: library&info@foodstandards.gsi.gov.uk

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Table 1: Fluorinated chemicals measured and number of concentrations exceeding LOD

Chemical	Abbrev.	Number > LOD
Perfluorooctanesulphonylamide	PFOSA	1
Perfluorobutane sulphonate	PFBS	2
Perfluorohexane sulphonate	PFHxS	1
Perfluorooctane sulphonate	PFOS	4
Perfluoropentanoic acid	PFPeA	0
Perfluorohexanoic acid	PFHxA	1
Perfluoroheptanoic acid	PFHpA	0
Perfluorooctanoic acid	PFOA	1
Perfluorononanoic acid	PFNA	1
Perfluorodecanoic acid	PFDeA	1
Perfluoroundecanoic acid	PFUnA	1
Perfluorododecanoic acid	PFDoA	1
Perfluorotetradecanoic acid	PFTdA	1
Perfluorohexadecanoic acid	PFHdA	0
Perfluorooctadecanoic acid	PFOdA	0

Table 2: Concentrations of PFOS and PFOA (microgram/kg) in samples from the 2004 Total Diet Study

Food Group	Concentrations (microgram/kg fresh weight)											
							<i>Lower bound</i>			<i>Upper bound</i>		
	PFOS			PFOA			Sum PFAS			Sum PFAS		
Bread	<20	±	<4	<5	±	<1	0	±	-	172	±	30
Miscellaneous cereals	<10	±	<2	<5	±	<1	0	±	-	165	±	29
Carcase meats	<10	±	2	<2	±	<0.4	0	±	-	154	±	27
Offal	<20	±	<4	<2	±	<0.4	0	±	-	232	±	36
Meat products	<10	±	<2	<2	±	<0.4	0	±	-	126	±	21
Poultry	<10	±	<2	<2	±	<0.4	0	±	-	153	±	27
Fish	<5	±	<1	<3	±	<0.6	0	±	-	92	±	17
Oils and fats	<0.5	±	<0.1	<1	±	<0.2	1	±	0.2	78	±	15
Eggs	1	±	0.2	<1	±	<0.2	1	±	0.2	86	±	16
Sugars & preserves	1	±	0.2	<1	±	<0.2	1	±	0.2	86	±	16
Green vegetables	<3	±	<0.6	<1	±	<0.2	0	±	-	105	±	20
Potatoes	10	±	2	1	±	0.2	58	±	11	120	±	23
Other vegetables	<3	±	<0.6	<10	±	<2	1	±	0.2	80	±	16
Canned vegetables	2	±	0.4	<5	±	<1	2	±	0.4	138	±	27
Fresh fruit	<2	±	<0.4	<5	±	<1	0	±	-	118	±	23
Fruit products	<1	±	<0.2	<5	±	<1	0	±	-	126	±	25
Beverages	<0.5	±	<0.1	<0.5	±	<0.1	0	±	-	13	±	2.5
Milk	<0.5	±	<0.1	<0.5	±	<0.1	0	±	-	24	±	4.7
Dairy products	<5	±	<1	<5	±	<1	0	±	-	299	±	56
Nuts	<2	±	<0.4	<5	±	<1	0	±	-	171	±	32

Note: * The concentrations of PFAS include contributions from PFBS. There is uncertainty as to the true concentrations of PFBS in the potatoes and other vegetables food group due to interfering peaks that may or may not represent related chemicals. If they are represent unrelated chemicals the true concentrations of PFAS would be 82 ± 15.4 and 50 ± 10 microgram/kg (*lower bound*) and 144 ± 28 and 129 ± 26 microgram/kg (*upper bound*) respectively in place of the values shown above. The higher concentrations have been used to estimate dietary intakes in Tables 3a, 3b, 4a and 4b.

Table 3a: Estimated average adult dietary intakes (microgram/kg bodyweight/day) of PFOS and PFOA from the whole diet in 2004

Food Group	Estimated AVERAGE adult dietary intakes (microgram/kg bodyweight/day)											
						<i>Lower bound</i>			<i>Upper bound</i>			
	PFOS			PFOA			Sum PFAS			Sum PFAS		
Bread	0.03	±	0.01	0.01	±	<0.01	0	±	-	0.29	±	0.05
Miscellaneous cereals	0.02	±	0.01	0.01	±	<0.01	0	±	-	0.40	±	0.07
Carcase meats	0.01	±	<0.01	<0.01	±	<0.01	0	±	-	0.17	±	0.03
Offal	0.01	±	<0.01	<0.01	±	<0.01	0	±	-	0.06	±	0.01
Meat products	0.01	±	<0.01	<0.01	±	<0.01	0	±	-	0.13	±	0.02
Poultry	0.01	±	<0.01	<0.01	±	<0.01	0	±	-	0.16	±	0.03
Fish	<0.01	±	<0.01	<0.01	±	<0.01	0	±	-	0.07	±	0.01
Oils and fats	<0.01	±	<0.01	<0.01	±	<0.01	<0.001	±	<0.001	0.02	±	0.00
Eggs	<0.01	±	<0.01	<0.01	±	<0.01	<0.001	±	<0.001	0.04	±	0.01
Sugars & preserves	<0.01	±	<0.01	<0.01	±	<0.01	<0.001	±	<0.001	0.04	±	0.01
Green vegetables	<0.01	±	<0.01	<0.01	±	<0.01	0	±	-	0.07	±	0.01
Potatoes	0.02	±	<0.01	<0.01	±	<0.01	0.1	±	0.02	0.23	±	0.04
Other vegetables	<0.01	±	<0.01	0.01	±	<0.01	0.002	±	<0.001	0.08	±	0.02
Canned vegetables	<0.01	±	<0.01	<0.01	±	<0.01	0.002	±	<0.001	0.11	±	0.02
Fresh fruit	<0.01	±	<0.01	0.01	±	<0.01	0	±	-	0.23	±	0.05
Fruit products	<0.01	±	<0.01	0.01	±	<0.01	0	±	-	0.20	±	0.04
Beverages	0.01		<0.01	0.01		<0.01	0		-	0.21		0.04
Milk	<0.01	±	<0.01	<0.01	±	<0.01	0	±	-	0.09	±	0.02
Dairy products	0.01	±	<0.01	0.01	±	<0.01	0	±	-	0.32	±	0.06
Nuts	<0.01	±	<0.01	<0.01	±	<0.01	0	±	-	0.03	±	0.01
Total	0.13	±	0.03	0.07	±	0.01	0.1	±	0.02	2.51	±	0.47

Notes: The intake of PFOS and PFOA by the average consumer for all foods combined is not equal to the sum of the intakes from the individual foods. It refers to the dietary intake by a consumer consuming one or any combination of the foods PFOS and PFOA. These values are derived from a distribution of the individual consumers' consumption patterns with regards to the individual foods.

Table 3b: Estimated high level adult dietary intakes (microgram/kg bodyweight/day) of PFOS and PFOA from the whole diet in 2004

Food Group	Estimated HIGH LEVEL adult dietary intakes (microgram/kg bodyweight/day)											
							<i>Lower bound</i>			<i>Upper bound</i>		
	PFOS			PFOA			Sum PFAS			Sum PFAS		
Bread	0.08	±	0.02	0.02	±	<0.01	0	±	-	0.67	±	0.12
Miscellaneous cereals	0.06	±	0.01	0.03	±	0.01	0	±	-	1.00	±	0.18
Carcase meats	0.03	±	0.01	0.01	±	<0.01	0	±	-	0.50	±	0.09
Offal	0.02	±	<0.01	<0.01	±	<0.01	0	±	-	0.21	±	0.04
Meat products	0.03	±	0.01	0.01	±	<0.01	0	±	-	0.42	±	0.07
Poultry	0.03	±	0.01	0.01	±	<0.01	0	±	-	0.50	±	0.09
Fish	0.01	±	<0.01	0.01	±	<0.01	0	±	-	0.21	±	0.04
Oils and fats	<0.01	±	<0.01	<0.01	±	<0.01	<0.001	±	<0.001	0.05	±	0.01
Eggs	<0.01	±	<0.01	<0.01	±	<0.01	0.002	±	<0.001	0.13	±	0.02
Sugars & preserves	<0.01	±	<0.01	<0.01	±	<0.01	0.002	±	<0.001	0.15	±	0.03
Green vegetables	0.01	±	<0.01	<0.01	±	<0.01	0	±	-	0.20	±	0.04
Potatoes	0.05	±	0.01	0.01	±	<0.01	0.3	±	0.05	0.53	±	0.10
Other vegetables	0.01	±	<0.01	0.03	±	0.01	0.003	±	<0.001	0.26	±	0.05
Canned vegetables	0.01	±	<0.01	0.01	±	<0.01	0.005	±	0.002	0.39	±	0.08
Fresh fruit	0.01	±	<0.01	0.03	±	0.01	0	±	-	0.75	±	0.15
Fruit products	0.01	±	<0.01	0.03	±	0.01	0	±	-	0.74	±	0.15
Beverages	0.02		<0.01	0.02		<0.01	0		-	0.45		0.09
Milk	0.01	±	<0.01	0.01	±	<0.01	0	±	-	0.23	±	0.05
Dairy products	0.02	±	<0.01	0.02	±	<0.01	0	±	-	1.02	±	0.19
Nuts	<0.01	±	<0.01	0.01	±	<0.01	0	±	-	0.15	±	0.03
Total	0.22	±	0.04	0.13	±	0.03	0.3	±	0.05	4.29	±	0.82

Notes: The intake of PFOS and PFOA by the high level consumer for all foods combined is not equal to the sum of the intakes from the individual foods. It refers to the dietary intake by a consumer consuming one or any combination of the foods PFOS and PFOA. These values are derived from a distribution of the individual consumers' consumption patterns with regards to the individual foods.

Table 4a: Estimated average dietary intakes (microgram/kg bodyweight/day) of PFOS, PFOA and PFAS by different age groups from the whole diet in 2004

Age group	Estimated average dietary intakes (microgram/kg bodyweight/day)					
	<i>Upper bound</i>		<i>Lower bound</i>		<i>Upper bound</i>	<i>Lower bound</i>
	PFOS	PFOA	PFOS	PFOA	PFAS	PFAS
Senior citizens - living at home	0.1 ± 0.02	0.05 ± 0.01	0.02 ± 0.003	0.001 ± <0.001	1.9 ± 0.4	0.09 ± 0.02
Senior citizens - in old peoples' homes	0.1 ± 0.02	0.06 ± 0.01	0.02 ± 0.003	0.002 ± <0.001	2.3 ± 0.4	0.09 ± 0.02
Adults	0.1 ± 0.03	0.07 ± 0.01	0.01 ± 0.003	0.001 ± <0.001	2.5 ± 0.5	0.1 ± 0.02
Schoolchildren:						
4-6 years	0.3 ± 0.05	0.1 ± 0.03	0.05 ± 0.009	0.004 ± 0.001	5.2 ± 1.0	0.3 ± 0.05
7-10 years	0.2 ± 0.04	0.1 ± 0.02	0.04 ± 0.008	0.004 ± 0.001	4.1 ± 0.8	0.2 ± 0.04
11-14 years	0.1 ± 0.03	0.07 ± 0.02	0.03 ± 0.006	0.003 ± 0.001	2.8 ± 0.5	0.2 ± 0.03
15-18 years	0.1 ± 0.02	0.06 ± 0.01	0.02 ± 0.005	0.002 ± <0.001	2.2 ± 0.4	0.1 ± 0.02
Toddlers:						
1.5-2.5 years	0.3 ± 0.05	0.2 ± 0.03	0.05 ± 0.01	0.004 ± 0.001	6.1 ± 1.1	0.3 ± 0.05
2.5-3.5 years	0.3 ± 0.05	0.1 ± 0.03	0.05 ± 0.009	0.004 ± 0.001	5.5 ± 1.0	0.2 ± 0.04
3.5-4.5 years	0.2 ± 0.05	0.1 ± 0.03	0.05 ± 0.009	0.004 ± 0.001	5.1 ± 0.9	0.2 ± 0.04

Table 4b: Estimated high level dietary intakes (microgram/kg bodyweight/day) of PFOS, PFOA and PFAS by different age groups from the whole diet in 2004

Age group	Estimated high level dietary intakes (microgram /kg bodyweight/day)																	
	<i>Upper bound</i>						<i>Lower bound</i>						<i>Upper bound</i>		<i>Lower bound</i>			
	PFOS			PFOA			PFOS			PFOA			PFAS		PFAS			
Senior citizens - living at home	0.2	±	0.03	0.1	±	0.02	0.04	±	0.007	0.004	±	<0.001	3.2	±	0.6	0.2	±	0.04
Senior citizens - in old peoples' homes	0.2	±	0.04	0.1	±	0.02	0.03	±	0.007	0.003	±	0.001	3.6	±	0.7	0.2	±	0.04
Adults	0.2	±	0.04	0.1	±	0.03	0.03	±	0.01	0.003	±	0.002	4.3	±	0.8	0.3	±	0.05
Schoolchildren:																		
4-6 years	0.4	±	0.08	0.2	±	0.05	0.09	±	0.02	0.009	±	0.002	8.4	±	1.6	0.5	±	0.09
7-10 years	0.3	±	0.06	0.2	±	0.04	0.09	±	0.02	0.009	±	0.002	6.5	±	1.2	0.5	±	0.1
11-14 years	0.2	±	0.05	0.1	±	0.03	0.07	±	0.01	0.006	±	0.001	4.2	±	0.9	0.4	±	0.07
15-18 years	0.2	±	0.04	0.1	±	0.02	0.05	±	0.01	0.005	±	0.001	3.8	±	0.7	0.3	±	0.05
Toddlers:																		
1.5-2.5 years	0.5	±	0.09	0.3	±	0.06	0.1	±	0.03	0.01	±	0.002	11	±	2.1	0.7	±	0.1
2.5-3.5 years	0.4	±	0.08	0.3	±	0.06	0.1	±	0.02	0.01	±	0.002	10	±	1.9	0.6	±	0.1
3.5-4.5 years	0.4	±	0.08	0.2	±	0.05	0.1	±	0.02	0.01	±	0.002	8.0	±	1.5	0.6	±	0.1