

EXTERNAL MEMORANDUM

FROM: Exponent
DATE: April 4, 2019
SUBJECT: Residual Per- and Polyfluorinated Alkyl Substances (PFAS) measured in Lion Apparel branded Turn-Out Gear

An initial screening investigation was conducted to gain insight into the presence of any polyfluorinated alkyl substances (PFAS) residuals in select exemplar Lion Apparel (Lion) branded fire-fighting turn-out gear. Lion provided Exponent with a variety of exemplar coat and pant models (listed in Table 1) for processing. A subset of representative gear samples was submitted to a commercial laboratory, AXYS-SGS Analytical laboratories (AXYS), for PFAS analysis. This memorandum summarizes the laboratory results of the select samples and provides some interpretation into significance of the concentrations of compounds reported.

Exemplar Selection for Analysis

To facilitate a general characterization of PFAS residuals in exemplar products, three (3) coats and one (1) pant were selected from the exemplar products provided by Lion Apparel. These exemplars involved four production years in an effort to provide insight into the presence of PFAS concentrations in Lion products as well as any changes over time. The exemplars provided and those selected for analysis are listed in Tables 1 and 2, respectively.

Cutting and Subsampling

Subsampling of the jacket and pants was determined based on areas of the garments that, when worn, would likely have direct contact with the skin. A total of fourteen (14) samples were submitted to AXYS. Subsampling was conducted as follows:

Sample selection

- Coat: subsamples were cut from the neck, elbow, and cuff areas.
- Pants: subsamples were cut from the waist, inner pocket, cuff areas.

Sampling procedure

- Using nitrile gloves and clean titanium scissors, samples were cut into 1- by 1-cm pieces and placed into clean PFAS-free sample containers provided by

AXYS. Scissors and work surface were cleaned with alcohol wipes between each sample.

- Samples were cut only from the thermal layer closest to the skin (refer to appended photos).
- 6–8 g of cut pieces were shipped in a cooler at room temperature directly to AXYS. The remaining exemplars are stored as shipped and remain with Exponent.

Laboratory Analysis

Laboratories with PFAS analytical capabilities generally apply their established methods developed for solid materials (e.g., soil, sediments, etc.) to PFAS extraction and analysis of consumer products. AXYS applied the extraction procedures described in method MLA-110.¹ Briefly, the analysis was conducted as follows:

- The laboratory selected approximately 1 g of cut pieces for extraction.
- The sample was spiked with an isotopically labelled surrogate standard.
- The sample was extracted in acetic acid and basic methanol, followed by a clean-up step before analysis using liquid chromatography with tandem mass spectrometry (LC/MS/MS).
- An internal standard and isotope dilution quantification was used to calculate final sample concentrations reported in units of ng/g or parts per billion (ppb).

PFAS Sample Results

The individual PFAS measured varied across the four products submitted. Tables 3–6² detail the individual PFAS and associated concentrations measured in selected samples. The results can be summarized as follows:

- The results generally indicate low levels of extractable individual and sum PFAS.
- Except for the 2014 exemplar, individual PFAS measured cover several classifications, including short-chain and long-chain³ perfluorinated carboxylic acids (PFCAs) and perfluorinated sulfonic acids (PFSAAs), as well as fluorotelomer sulfonates and precursor PFAS.
- The individual types and numbers of PFAS detected in each sample is variable and there appears to be no clear trend in concentrations over time.

¹ The methods as provided by the laboratory are available for review.

² Table 7 provides a list of definitions and formulas for the PFAS analyzed and reported.

³ Long-chain perfluorinated alkyl carboxylic acids (PFCAs) contain eight carbons or greater. These compounds contain eight or more carbons that are fully fluorinated or perfluorinated carbons; Long-chain perfluorinated sulfonates (PFSAAs) contain six carbons or greater. These compounds contain six or more fully fluorinated or perfluorinated carbons

This is likely attributable to the sources and amount of treatment product applied to the coats and pants. A separate assessment of the treatment product(s) would facilitate further evaluation of the differences observed in individual PFAS detected.

- The measured concentrations of PFOA and PFOS in the submitted samples are listed below.

Exemplar Sample	Year	PFOA (ng/g or ppb)	PFOS (ng/g or ppb)
CB2X/7700214432	2007	5.58–8.89	Non-detect
PSUM/5283432	2011	1.7–23.5	Non-detect
CYFM/7076492	2014	0.273–19.1	Non-detect
CCHX (42+48r)/7702446562	2018	Non-detect–0.959	Non-detect–0.37

- Based on our knowledge of the industry, the use of long chain PFAS chemistries has been phased out by most manufacturers in the United States (production in countries like China has continued). Many manufacturers of fabric treatment products have shifted to the use of shorter-chain chemistries; examples include PFBA and PFHxA as replacements for PFOA and PFBS and PFHxS as replacements for PFOS.
- Although these changes have been made, manufacturing and associated treatments of materials generally occur in the same plants where the long chain chemistries were previously applied. As a result, residual PFAS may still occur in final products. The source of these long chain chemistries in the garments we tested is not clear from our limited analysis. In other words, from our analysis we cannot conclude whether the detected long chain PFAS are components of the textile treatment or a result of manufacturing residuals.

These final concentrations represent the amount of PFAS found in the textile layer, but are not representative of an exposure concentration either by absorption through skin or by inhalation. An estimate of exposure concentration would require additional analysis of the leaching potential of PFAS from the fabric.

Regulatory Guidance on PFOA and PFOS

There are currently no federal or state regulatory guidelines in the United States for PFAS in textiles. However, some international guidelines are available for PFOA and PFOS.

- Per Annex B of the Stockholm Convention European Union (EU) Persistent Organic Pollutants (POPs) regulation, the limit for PFOS and its derivatives is 10 mg/kg when it occurs in substances or in preparations, which as written is also likely applicable to textiles.
- The independent International Association for Research and Testing in the Field of Textile and Leather Ecology (OEKO-TEX®), which publishes voluntary guidance limits on residual chemical levels in textiles, recently published a supplement to their Standard 100 for limit values in clothing. The supplement identifies a limit value for PFOA in personal protective equipment (PPE, which includes fire-fighting gear) of 25 ng/g.

The results from analysis of a limited number of Lion fire-fighting garments indicate that PFOA and PFOS levels are below the established international limits described above.

Table 1. Exemplar samples provided by Lion Apparel. Samples from line items highlighted in bold text were submitted for analysis

ITEM #	Date of Manufacture	Model	Serial Number	Item	Cut	Moisture Barrier
3	3/5/2007	CB2X	7700214432-liner 7700214431-shell	Coat	10960000015-liner 109600AA015-shell	RT7100
10	3/4/2010	CVFM	4537982-liner 4537981-shell	V-Force Coat	122109AA001-liner 12210900001-shell	Crosstech
7	9/24/2010	CVFM	4828292-liner 4828291-shell	V-Force Coat	12471500001-liner 12471500001-shell	Crosstech
6	1/25/2011	CSTM	0005023952-liner 0005023951-shell	Super Deluxe Coat	126012AA001-liner 12601200001-shell	Crosstech
5	6/28/2011	PSUM	0005283432-liner 5283431-shell	Super Pant	127907AD018-liner 12790700018-shell	Crosstech Quilt
9	6/28/2011	PSUM	5283432	Pant	127907AD018	Crosstech
11	4/27/2012	CSTM	5624582-liner 5624581-shell	Super Deluxe Coat	130764AA001-liner 13076400001-shell	Crosstech
2	7/8/2012	DLBM	5735982 5735981	Pant	131727AF013-pant 13172700013-shell	RT7100
8	7/8/2012	PLBM	5735971-shell	Pant	13172700012	
1	10/1/2013	PSDM	6469372 6469371	Pant	137693AA006-liner 13769300006-shell	Crosstech
4	12/1/2014	CYFM	0007076492-liner 007076491-shell	Coat	143442AA001-liner 14344200001	RT7100
12	12/1/2014	CSTM	7072121-shell	Super Deluxe Coat	143415000035	N/A
	2018	CCHX=42	7702446562	Coat	168142AA011	K7

Table 2. Items selected for laboratory analysis from exemplar provided by Lion Apparel and the areas from which samples were cut.

Date of Manufacture	Model	Serial Number	Item	Cut	Moisture Barrier	Samples	# samples
3/5/2007	CB2X	7700214432- liner	Coat	10960000015- liner	RT7100	Cuff, neck area, elbow area, moisture barrier sample	4
6/28/2011	PSUM	5283432	Pant	127907AD018	Crosstech	Leg opening, waist area, moisture barrier sample	4
12/1/2014	CSTM	7072121- shell	Super Deluxe Coat	143415000035	N/A	Cuff, neck area, elbow area	3
2018	CCHX=42	7702446562	Coat	168142AA011	K7	Cuff, neck area, elbow area	3

Table 3. Individual PFAS and associated concentrations measured in exemplar coat CB2X/7700214432 produced in 2007. Only compounds with detectable concentrations are listed. ND – the individual PFAS was not detected in the sample.

Sample ID/Sample	EXPO 2A Neck Area	EXPO 2B Liner	EXPO 2C Elbow Area	EXPO 2D Cuff
Product Model/SN	CB2X/7700214432	CB2X/7700214432	CB2X/7700214432	CB2X/7700214432
Product Year	2007	2007	2007	2007
UNITS	(ng/g or ppb)	(ng/g or ppb)	(ng/g or ppb)	(ng/g or ppb)
PFBA	1.81	ND	ND	ND
PFPeA	2.01	0.545	0.802	0.422
PFHxA	3.18	1.49	1.73	1.46
PFHpA	3.15	2.26	1.59	2.12
PFOA	7.49	7.04	5.58	8.89
PFNA	3.7	7.15	1.7	5.36
PFDA	1.6	3.67	1.37	2.67
PFUnA	0.553	2.16	0.314	1.2
PFDoA	0.208	2.37	0.984	0.48
PFTTrDA	ND	2.87	ND	ND
PFTeDA	ND	0.643	ND	ND
PFBS	ND	0.421	ND	ND
PFOS	ND	2.1	ND	ND
6:2 FTS	0.938	0.968	ND	ND

Table 4. Individual PFAS and associated concentrations measured in exemplar pant PSUM/5283432 produced in 2011. Only compounds with detectable concentrations are listed. ND – the individual PFAS was not detected in the sample.

Sample ID/Sample Product Model/SN Product Year UNITS	EXPO 1A Waist Area PSUM/5283432 2011 (ng/g or ppb)	EXPO 1B Liner PSUM/5283432 2011 (ng/g or ppb)	EXPO 1C Pant Cuff PSUM/5283432 2011 (ng/g or ppb)	EXPO 1D Pocket (Inner - yellow fabric) PSUM/5283432 2011 (ng/g or ppb)
PFBA	0.82	ND	ND	0.95
PFPeA	0.507	ND	ND	1.13
PFHxA	1.75	2.4	1.94	5.51
PFHpA	0.696	1.08	1.24	3.63
PFOA	1.7	9.72	7.08	23.5
PFNA	0.244	1.29	1.32	3.29
PFDA	0.476	6.92	17.9	25.2
PFUnA	ND	0.681	0.923	1.28
PFDoA	ND	3.1	12.4	12.2
PFTTrDA	ND	0.645	0.753	0.602
PFTeDA	ND	0.861	6.74	4.17
PFBS	ND	0.305	0.231	ND
6:2 FTS	0.852	7.52	1.13	3.75
PFOSA	ND	ND	0.457	ND
N-EtFOSA	ND	ND	0.811	ND
MeFOSAA	ND	ND	0.284	ND
N-MeFOSE	ND	ND	7.65	ND
N-EtFOSE	ND	ND	7.01	ND

Table 5. Individual PFAS and associated concentrations measured in exemplar coat CYFM/7076492 produced in 2014. Only compounds with detectable concentrations are listed. ND – the individual PFAS was not detected in the sample.

Sample ID/Sample Product Model/SN Product Year UNITS	EXPO 3A Neck Area CYFM/7076492 2014 (ng/g or ppb)	EXPO 3B Elbow Area CYFM/7076492 2014 (ng/g or ppb)	EXPO 3C Cuff CYFM/7076492 2014 (ng/g or ppb)
PFBA	ND	ND	2.25
PFPeA	ND	ND	0.971
PFHxA	0.56	0.765	4.1
PFHpA	ND	0.306	2.14
PFOA	0.273	3.82	19.1
PFNA	ND	0.483	2.19
PFDA	ND	3.71	18.9
PFUnA	ND	0.283	0.93
PFDoA	ND	2.73	11.4
PFTrDA	ND	ND	0.471
PFTeDA	ND	1.27	4.67
PFBS	ND	ND	0.346

Table 6. Individual PFAS and associated concentrations measured in exemplar coat CCHX (42+48r/7702446562 produced in 2018. Only compounds with detectable concentrations are listed. ND – the individual PFAS was not detected in the sample.

CLIENT_ID Product Model/ISN Product Year UNITS	EXPO 4A - Elbow Area CCHX = 42/7702446562 2018 (ng/g or ppb)	EXPO 4B - Cuff CCHX = 42/7702446562 2018 (ng/g or ppb)	EXPO 4C - Neck CCHX = 42/7702446562 2018 (ng/g or ppb)
PFBA	ND	4.8	ND
PFPeA	ND	5.65	ND
PFHxA	ND	25.3	ND
PFHpA	ND	7.03	ND
PFOA	ND	0.959	ND
PFNA	ND	0.203	ND
PFDA	ND	0.918	0.304
PFUnA	ND	ND	0.463
PFDoA	ND	0.309	0.637
PFTTrDA	ND	ND	0.465
PFHpS	ND	ND	0.441
PFOS	ND	ND	0.224
PFNS	ND	ND	0.37
PFDS	ND	ND	0.431
PFDoS	ND	ND	0.686
6:2 FTS	ND	ND	0.283
8:2 FTS	ND	0.792	ND
PFOSA	ND	11	1.43
N-MeFOSA	ND	ND	0.853
N-EtFOSA	ND	ND	0.727
MeFOSAA	ND	ND	1.77
EtFOSAA	ND	ND	0.661
N-MeFOSE	ND	ND	0.948
N-EtFOSE	ND	ND	8.94
			7.18

Table 7. List of PFAS analyzed and reported.

Acronym	Definition	Formula
PFBA	Perfluorobutanoic acid	C3F7COOH
PFPeA	Perfluoropentanoic acid	C4F9COOH
PFHxA	Perfluorohexanoic acid	C5F11COOH
PFHpA	Perfluoroheptanoic acid	C6F13COOH
PFOA	Perfluorooctanoic acid	C7F15COOH
PFNA	Perfluorononanoic acid	C8F17COOH
PFDA	Perfluorodecanoic acid	C9F19COOH
PFUnA	Perfluoroundecanoic acid	C10F21COOH
PFDoA	Perfluorododecanoic acid	C11F23COOH
PFTTrDA	Perfluorotridecanoic acid	C12F25COOH
PFTeDA	Perfluorotetradecanoic acid	C13F27COOH
PFBS	Perfluorobutane sulfonic acid	C4F9SO3H
PFPeS	Perfluoropentane sulfonic acid	C5F11SO3H
PFHxS	Perfluorohexane sulfonic acid	C6F13SO3H
PFHpS	Perfluoroheptane sulfonic acid	C7F15SO3H
PFOS	Perfluorooctane sulfonic acid	C8F17SO3H
PFNS	Perfluorononane sulfonic acid	C9F19SO3H
PFDS	Perfluorodecane sulfonic acid	C10F21SO3H
PFDoS	Perfluorododecane sulfonic acid	C12F25SO3H
4:2 FTS	4:2 Fluorotelomer sulfonic acid	C4F9CH2CH2SO3H
6:2 FTS	6:2 Fluorotelomer sulfonic acid	C6F13CH2CH2SO3H
8:2 FTS	8:2 Fluorotelomer sulfonic acid	C8F17CH2CH2SO3H
PFOSA	Perfluorooctane sulfonamide	C8F17SO2NH2
N-MeFOSA	N-Methyl perfluorooctane sulfonamide	C8F17SO2NH(CH3)
N-EtFOSA	N-Ethyl perfluorooctane sulfonamide	C8F17SO2NH(C2H5) (sulfuramid)
MeFOSAA	N-Ethyl perfluorooctane sulfonamidoacetic acid	C8F17SO2N(C2H5)CH2COOH
EtFOSAA	N-Methyl perfluorooctane sulfonamidoacetic acid	C8F17SO2N(CH3)CH2COOH
N-MeFOSE	N-Methyl perfluorooctane sulfonamidoethanol	C8F17SO2N(CH3)CH2CH2OH
N-EtFOSE	N-Ethyl perfluorooctane sulfonamidoethanol	C8F17SO2N(C2H5)CH2CH2OH