Hazardous chemicals in branded textile products on sale in 25 countries/regions during 2013

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Executive Summary

Previous investigation by Greenpeace have shown that a wide range of textile products, manufactured and sold in many countries around the world, can contain residues of hazardous substances, including hormone-disrupting alkylphenols and their ethoxylates, reprotoxic phthalates and, in some cases, azo dye precursors of carcinogenic amines. This study extends this work to include a set of 82 additional clothing and footwear products purchased between May and June 2013, which included articles sold by 12 different major clothing brands and purchased in 25 countries/regions around the world. The range included examples manufactured in at least 12 different countries, although the countries of manufacture of 12 articles could not be determined. Furthermore, this investigation extends the range of chemical residues tested for in a sub-set of the products to include organotins (in 21 articles with plastisol printed fabric, five footwear articles and six sports tops), perfluorinated chemicals (PFCs, in seven waterproof clothing articles, three footwear articles, and five articles of swimwear) and antimony (in products containing polyester-based fabrics). Details of the analyses carried out and information on the various chemicals quantified in this study are provided within this report.

Nonylphenol ethoxylates (NPEs) were detected in fabric from 50 articles, 61% of the 82 articles investigated, with concentrations ranging from 1.2 to 17 000 mg/kg. Eight articles (10% of the samples) contained NPEs at concentrations above 100 mg/kg and, in three of these, over 1000 mg/kg (0.1% by mass).

NPEs were detected in at least one article from each of the brands included in this study. Furthermore, NPEs were found in one or more articles purchased in 21 out of the 25 countries/regions, and with examples for 10 of the 12 countries of manufacture. These results are consistent with our previous investigations of related textile products, confirming the presence of NPEs residues in many clothing articles, and at substantial levels for some of these.

NPE residues within textile products are readily released when the items are washed as part of their normal use (Brigden *et al.* 2012, Greenpeace 2012b). In addition, these results suggest the widespread use of NPEs during the manufacture of the textiles analysed, which would be expected to have resulted in releases of NPEs and nonylphenol to the environment.

The use of NPEs during textile manufacture is regulated in the EU and some other individual countries, though ongoing use is permitted in many others, including countries in which many of the articles investigated in this study were known to have been manufactured. However, no regulations currently exist anywhere in the world that restrict the sale of textile products containing NPE residues, though such a regulation is currently under development within the EU (KEMI 2012). In order to offer adequate protection, such regulations will need to set any limit for NPEs in products as low as possible and cover as wide a range of NPEs as possible.

Phthalates were detected in sections of printed fabric from 33 of the 35 articles investigated, at levels above the detection limit of 3 mg/kg. Total phthalate concentrations in these 33 ranged from 5.6 110 000 mg/kg. The levels and types of individual phthalates found in printed sections from these articles are consistent with previous investigations of related textile products. Concentrations above 1000 mg/kg (0.1% by mass) were found for two articles, a Primark t-shirt purchased in Germany (TX13094), which contained a particularly high concentration of DEHP (110 000 mg/kg, 11.0% by weight in the printed section of fabric), and a baby one-piece from American Apparel purchased in the US (TX13015), with a lower but still relevant level of another phthalate, DINP (5900 mg/kg, 0.59% by weight of the printed section).

The high concentrations of phthalates in two articles, including the reprotoxic form DEHP in one case, suggest their use as plasticisers within the plastisol formulations used to manufacture these products, while the presence of lower levels in many other articles illustrates the widespread distribution of these chemicals as ingredients and/or contaminants in industrial processes. The sale of textiles products containing phthalates is not currently regulated in any of the countries where the articles were purchased, though in China draft limits on the presence of six phthalates (including DEHP and DINP) in clothes sold for babies and young children are under consideration (SAC 2012b).

Organotin compounds were detected in sections of printed fabric from three articles (of 21 tested), and in materials from three footwear articles (of five tested), but not in any of the six sportswear items. Different individual organotins were identified in the footwear articles compared to those found in the printed fabrics and, where detected, concentrations in footwear articles were generally far higher compared to those for printed articles.

The compounds identified in materials from footwear were monooctyltin (MOT, 0.26-34 mg/kg) and dioctyltin (DOT, 0.18-369 mg/kg), while monobutyltin (MBT, 0.14-0.48 mg/kg) was detected in the three printed fabrics that tested positive, and dibutyltin (DBT, 0.14-0.16 mg/kg) was also detected in a number of materials from one of these (TX13009).

Organotins are known to be toxic at relatively low levels of exposure to a range of organisms, including mammals, with immunotoxicity, impact on development and neurotoxicity in mammalian systems. In the EU there is regulation of certain organotins in textile and other consumer products, including DBT and DOT, though none of the tested articles had concentrations above the EU limits, including those articles sold outside the EU.

At least one per- or polyfluorinated chemical (PFC) was detected in each of the 15 articles. Ionic PFCs, predominantly perfluorosulfonates (PFASs) and perfluorinated carboxylic acids (PFCAs), were more commonly detected, with examples being found in all but one article. Examples of volatile PFCs, predominantly fluorotelomer alcohols (FTOHs), were detected in five of the 15 articles (four of the seven waterproof clothing articles and one footwear article). Where volatile PFCs were detected, however, they were generally found in considerably higher concentrations than ionic PFCs.

The highest concentration of ionic PFCs for all articles was detected in one sample from waterproof trousers sold by H&M (2290 μg/kg, TX13067a), though the concentration in another portion from the same article was substantially lower (26.4 μg/kg, TX13067b). For the sample with the second highest concentration, Adidas swimwear (TX13006), both portions contained the same total ionic PFC concentration (68.0 mg/kg, in both TX13006a and TX13006b), more than 30 times lower than the highest recorded value in this study (for TX13067a).

Median values, calculated excluding the high values for TX13067a, were 10.2 μg/kg (waterproof clothing), 2.69 μg/kg (footwear articles) and 3.51 μg/kg (swimwear). Of these, shoes sold by Puma had the highest total ionic PFC concentration among footwear samples (25.2 μg/kg, TX13097), while for swimwear, a product sold by Adidas showed the highest levels (68.0 μg/kg, TX13006a/b). Among the waterproof clothing articles, the C-6 PFSA (perfluorohexane sulfonate, PFHxS) was the predominant ionic PFC for three coats, two sold by H&M and another by Primark.

PFC content in some other articles was dominated by PFCAs, predominantly the C4-acid (perfluorobutanoic acid, PFBA) and the C8-acid (perfluorooctanoic acid, PFOA). The highest PFOA concentration was found in two samples from an Adidas swimwear article (65.8-68.8 μg/kg equivalent to 14.5-15.3 $\mu g/m^2$), approximately nine times greater than the next highest concentration. Our investigations have shown that concentrations of ionic PFCs can vary widely not only between products but also within different parts of the same product. Quality control checks confirm that differences in PFC levels measured for different parts of individual clothing articles reflect real variations in concentrations within the clothing, and do not result from the testing method. Though the within-article variations were determined using products manufactured by certain brands, the reported variations are likely not only to be a reflection on the products sold by those brands alone, but rather a characteristic of textile products treated with PFCs in general. The full extent of such variations, and the underlying causes, deserve further investigation.

In addition to the ionic PFCs, volatile PFCs were detected in five of the 15 articles tested (at concentrations ranging from 380-6970 μg/kg), predominantly in waterproof clothing articles (four of seven clothing articles tested). The highest concentration was found in a Nike coat (6970 μg/kg), followed by an Adidas coat (2420 μg/kg) and a Uniqlo jacket (2350 μg/kg). No volatile PFCs were detected in any of the swimwear articles.

Where detected, the total concentration of volatile PFCs was between 51 and 1110 times higher than the total concentration of ionic PFCs in the same articles. The predominant volatile PFCs detected were two fluorotelomer alcohols (8:2 FTOH and 10:2 FTOH) and two fluorotelomer acrylates (8:2 FTA and 10:2 FTA). All these compounds can act as sources of highly persistent PFCAs, such as PFOA and PFDA.

PFCs are used in some textile products because of their chemical stability and ability to repel both water and oil, the very same properties that mean that many PFCs, especially the longer-chain forms found in several of the articles tested, are highly persistent or degrade to persistent by-products. PFCs can be toxic to animals during development and adulthood; for example, some, including PFOA, show hormone-disrupting properties, while both PFOS and PFOA exhibit reproductive toxicity.

Despite these concerns, beyond a limit value of 1 $\mu g/m^2$ for PFOS in textiles in Europe, there are few other controls on PFC residues in products. Although the levels of PFOS found in the current study (0.855 $\mu g/m^2$ in an Adidas shoe, 0.464 $\mu g/m^2$ in an item of Burberry swimwear and 0.954 $\mu g/m^2$ in a H&M coat) were below this specified limit, other PFCs, some showing similar properties to PFOS, are not currently subject to regulation despite being found in far higher concentrations in many of the products tested.

Antimony, used as a catalyst during polyester manufacture, was detected in fabrics from all 36 articles investigated, which were composed either of polyester, or a blend of polyester and other fibres. Antimony concentrations in the fabrics ranged from range 14-293 mg/kg (median = 96 mg/kg). Concentrations calculated for the polyester fraction of each fabric were consistent with levels commonly reported for commercial polyester fibres (Duh 2002, Lacasse & Baumann 2004).

Despite known and suspected toxicity for antimony trioxide, and despite the availability of alternative catalysts for polyester manufacture, no regulations currently exist which prohibit use in textile manufacture.

In addition to the above chemicals, sections of dark or deeply coloured sections from 41 articles were investigated for carcinogenic amines which can be released from certain azo dyes, though none showed the presence of such amines at levels above the detection limit of 5mg/kg.

In conclusion, the results from the current study are broadly consistent with the findings from our previous studies for NPE, phthalates and PFCs (Greenpeace 2011, Greenpeace 2012a, Greenpeace 2012c), and provide additional evidence for the presence of residues of additional hazardous chemicals (organotins and antimony) in some textile products of this type. Overall, this study provides a further snapshot, across a diverse range of brands and of countries of manufacture and sale, of what appears to be a more generic problem, one that is not restricted to any particular country, product type or brand, and one that deserves further investigation including from a regulatory perspective.

1. Introduction

Finished textile products can contain certain hazardous chemicals used during their manufacture, either because of their use as components of materials incorporated within the product, or due to residues remaining from the use within processes employed during manufacture. This study follows on from, and extends, research recently published by Greenpeace International that identified a range of hazardous chemicals in textile products sold by major brands (Brigden *et al*. 2012, Greenpeace 2011a, Greenpeace 2012a).

These previous studies determined the concentrations of nonylphenol ethoxylates (NPEs) in a broad range of textile clothing products. The later study also determined the concentrations of carcinogenic amines released from azo dyes within dyed fabric and phthalate esters (commonly referred to as phthalates) in fabrics bearing a plastisol print – a suspension of plastic particles, commonly PVC or EVA, in a plasticiser. Used as ink for screen-printing images and logos onto textiles as well as using a broader qualitative chemical screening method to identify the presence, as far as possible, of other hazardous chemicals present within some of the products. These previous studies also summarise information from other related studies that have reported the presence in textile products of NPEs (Brigden *et al*. 2012 and references within), carcinogenic amines released under reducing conditions from azo dyes (JRC 2008, Laursen *et al*. 2003) and phthalates in plastisol printed fabric (RAPEX 2012, Greenpeace 2004).

This current study determined the concentrations of a broader range of hazardous chemicals in a variety of textile clothing and footwear products, consisting of 82 products across many countries of manufacture and sale, and representative of a wide range of major clothing brands. In addition to the hazardous chemicals included in the previous reports, this current study also investigated the concentration of perfluorinated and polyfluorinated compounds (PFCs) and of antimony in certain products.

More information on the chemicals investigated in the current study is provided in Boxes A-F.

2. Materials and methods

The 82 products were purchased in May and June 2013 at the flagship stores of the clothing brands, or other stores authorised to sell the branded products. The products were predominantly clothing items, including swimwear, though also included four footwear articles. While still in the store, purchased products were immediately sealed in individual identical clean polyethylene bags. Sealed bags containing the products were sent to the Greenpeace Research Laboratories at the University of Exeter in the UK, from where they were dispatched to independent accredited laboratories for a range of analyses as detailed below. In addition, all articles with fabrics composed of polyester, or a blend of polyester and other fibres (36 articles in total), were analysed at the Greenpeace Research Laboratories to determine the concentration of antimony within the polyester fibre. Details of the individual articles are provided in Appendix 1.

2.1 Nonylphenol ethoxylates (NPEs)

The concentrations of NPEs were quantified in a section of fabric from each of the 82 articles of clothing or footwear. Following isolation of a section of fabric from each article, the sample was extracted with an acetonitrile-water mixture in the ratio 70:30 and then analysed with reversed-phase HPLC liquid chromatography along with Applied Biosystems' API 4000 tandem mass spectrometry (LC-MS/MS). The quantification was carried out for each of 17 individual nonylphenol ethoxylates, consisting of those with between four and 20 ethoxylate groups. The quantitative results presented below are the sum of the concentrations of the individual nonylphenol ethoxylates with 4-20 ethoxylate groups, with a detection limit of 1 mg/kg.

2.2 Carcinogenic amines released under reducing conditions

Forty-one articles that included dark or deeply coloured sections of fabric were investigated for the concentrations of carcinogenic amines released under certain reducing conditions from those dyed sections, related to the potential presence of certain azo dyes. The samples were tested in accordance with method EN 14362 related to the relevant EU regulations (EU 2002). This involved the determination of certain aromatic amines derived from azo colorants following cleavage of the azo group under reducing conditions, either directly or following extraction from the fabric (depending on the type of fabric in each sample) with a detection limit of 5 mg/kg for each amine.

2.3 Phthalates in plastisol prints

For 35 articles bearing a medium or large-sized plastisol print of an image, logo or text, the concentrations of a range of phthalates were determined within the printed section of fabric. Details of the individual phthalates quantified in a section of printed fabric from each article are given in Appendix 2. A portion of each sample bearing a plastisol print was extracted with ethyl acetate:cyclohexane (1:1) using deuterated (D8)-naphthalene as a quality control standard to check extraction efficiency. The concentrations of phthalates in the extracts were subsequently analysed by gas chromatography/mass spectrometry (GC/MS) using an Agilent 5973 single quadropole mass detector with a programmed temperature vaporising (PTV) injector and a DB5ms column using deuterated (D10)-pyrene as an internal standard, with a detection limit of 3 mg/kg for each individual phthalate.

2.4 Organotins

Thirty-two articles were quantified for a range of organotins, consisting of 21 articles bearing a large plastisol print, five footwear articles and six sportswear articles. For some articles, which were composed of a mixture of fabric or print colours, a number of different sub-samples from the article were analysed. Details of the individual organotin quantified in each article are given in Appendix 3. Each sample was extracted with methanol. Organotins in the extract were derivatised using sodium tetraethylborate and extracted into hexane. Analysis of the final extract was carried out using GC/MS, with a detection limit of 0.1 mg/kg for each individual organotins.

2.5 PFCs

Fifteen articles, consisting of seven waterproof clothing articles, three footwear articles and five swimwear articles, were analysed for a range of perfluorinated and polyfluorinated compounds (PFCs). Details of the individual PFCs quantified in each article and their detection limits in individual samples are given in Appendix 4. For five articles (three waterproof clothing articles, one footwear article and one swimwear article), two different portions from each article were analysed separately for ionic PFCs, to determine variation in concentrations in different parts of the article. For analysis, a sample was cut from each article where there was no printing or labelling. Two separate analyses were carried out on each sample. One portion was extracted with methanol using Soxhlet extraction, the extract purified using solid phase extraction (SPE), and a range of ionic PFCs were quantified using high-performance liquid chromatography (HPLC) combined with tandem mass spectrometry (HPLC-MS/MS). A second portion was extracted with methyl tertiary butyl ether (MTBE) using ultrasonic extraction, and a range of volatile neutral PFCs were quantified using gas chromatography-mass spectrometry (GC-MS).

2.6 Antimony in polyester fibre

Thirty-six articles with fabrics composed of polyester, or a blend of polyester and other fibres, were analysed to determine the concentration of antimony within the polyester fibre. For each sample, a 1g portion was extracted using 20 ml of a mixture of nitric acid and hydrochloric acid (4:1). The acidified samples were digested firstly overnight at room temperature, then using microwave-assisted digestion with a CEM MARS Xpress system, with a temperature ramp to 180°C over 30 minutes followed by holding at 180°C for a further 15 minutes. Cooled digests were filtered and made up to 50 ml with deionised water. Sample digests were analysed by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES) using a Varian MPX Simultaneous Spectrometer, with a detection limit of 1 mg/kg.

3. Results and Discussion

The results for the various substance groups are presented in the following sections. Results from all analyses for the individual articles are provided in Appendix 1, along with a breakdown of the concentrations of individual phthalates in the relevant articles in Appendix 2, a breakdown of the concentrations of individual organotins in the relevant articles in Appendix 3, and a breakdown of the concentrations of individual PFCs in the relevant articles in Appendix 4.

3.1 Nonylphenol ethoxylates (NPEs)

Of the 82 articles in which NPEs were quantified, 50 articles (61% of the total) tested positive for the presence of NPEs at concentrations above the limit of detection (1 mg/kg), with concentrations ranging from just above 1 mg/kg up to 17 000 mg/kg. The highest concentration was detected in a C&A branded shoe manufactured and sold in Mexico (TX13030).

Eight articles (10% of the samples) contained NPEs at concentrations above 100 mg/kg and, of these, three samples (4% of articles tested) had concentrations over 1 000 mg/kg (0.1% by mass). A summary of the number of samples containing NPEs within various ranges of concentration is given in Table 1, and details for all articles are given in Appendix 1.

NPE concentration range (mg/kg)	Number of samples of 82 analysed	% of samples
<1	32	39%
1 – 10	20	25%
>10 – 100	22	27%
>100 – 1 000	5	6%
>1 000	3	4%

Table 1. The number of samples (of the 82 articles tested) within various NPE concentration ranges.

Breakdown of results by brand, place of sale and place of manufacture

A summary of the results is presented in Tables 2 to 4, which include a breakdown of the results by brand, by place of sale, and by country of manufacture, respectively. These tables include the median values for all samples in each brand, place of sale or country of manufacture, as well as the median value for only those samples in which NPEs were detected in each case.

NPEs were detected in at least one article from every brand (See Table 2). NPEs were detected in one or more product purchased in 21 out of the 25 countries/regions (See Table 3). NPEs were not detected in the articles purchased in Chile, Italy, Poland or Russia, though for each of these only one or two articles were purchased in each country, too few to draw any general conclusions about the absence of NPEs in articles sold in these countries.

NPEs were detected in one or more product from 10 of the 12 countries of manufacture (See Table 4). For 12 articles, the country of manufacture was not specified and could not be determined. NPEs were not detected in the articles that had been manufactured in India or Italy, though for these only one article was manufactured in each country, too few to draw any general conclusions about the absence of NPEs in articles manufactured in either country. The concentration for the single sample manufactured in Mexico (17 000 mg/kg) was considerably higher than that for any other countries of manufacture, though again only a single sample manufactured in Mexico was analysed, so again it is not possible to draw more general conclusions on the basis of this single data.

Brand	Number of samples	Number tested positive	NPE concentration range, when detected (mg/kg)	Median of detected levels (mg/kg)	Median of all levels (mg/kg)
Adidas	11	5	1.8 - 38	16	<1.0
American Apparel	4	3	25 - 2000	660	340
Burberry	9	6	27 - 780	58	33
C&A	7	3	2.9 – 17 000	46	<1.0
Disney	5	4	1.6 - 3900	50	30
GAP	11	4	2.5 - 34	6.3	<1.0
H&M	7	6	1.7 - 89	10	7.9
Li Ning	4	3	2.1 - 5.1	3.3	2.7
Nike	9	5	2.4 - 22	5.6	2.4
Primark	6	5	1.2 - 480	48	30
Puma	6	5	5.5 - 340	17	12
Uniqlo	3	1	26	26	<1.0
Total	82	50	1.2 – 17 000	21	3.1

Table 2. The number of samples in which NPEs were identified arranged by product brand, with the NPE concentration ranges, the median NPE concentrations in all samples, and the median values for those samples in which NPEs were detected for each brand.

Place of sale	Number of samples	Number tested positive	NPE concentration range, when detected (mg/kg)	Median of detected levels (mg/kg)	Median of all levels (mg/kg)
Argentina	1	1	2.4	2.4	2.4
Austria	4	2	12 - 480	250	6.3
Chile	1	0	<1.0	<1.0	<1.0
China	10	6	3.3 - 3900	9.7	4.2
Hong Kong	4	4	2.5 - 390	23	23
Taiwan	3	2	1.8 - 27	14	1.8
Columbia	2	1	3.4	3.4	2
Germany	6	5	1.2 - 25	6.3	4.2
Greece	3	2	5.5 - 38	22	5.5
Hungary	2	2	8.7 - 46	27	27
Indonesia	4	2	9.2 - 340	175	4.9
Israel	3	1	2.5	2.5	<1.0
Italy	1	0	<1.0	v	<1.0
Japan	4	3	25 - 34	26	26
Mexico	2	1	17 000	17 000	8500
Philippines	3	1	38	38	<1.0
Poland	2	0	<1.0	<1.0	<1.0
Russia	1	0	<1.0	<1.0	<1.0
Spain	5	4	7.9 - 70	41	33
Sweden	4	2	19 - 89	54	10
Switzerland	2	2	2.9 - 22	12	12
Thailand	3	1	1.7	1.7	<1.0
Turkey	5	3	5.6 - 62	17	5.6
UK	4	3	58 - 780	660	360
USA	3	2	1.6 - 2000	1000	1.6
Total	82	50	1.2 – 17 000	21	3.1

Table 3. The number of samples in which NPEs were identified arranged by the place of sale, with the NPE concentration range, the median NPE concentrations in all samples, and the median values for those samples in which NPEs were detected, for each place.

Place of manufacture	Number of samples	Number tested positive	NPE concentration range, when detected (mg/kg)	Median of detected levels (mg/kg)	Median of all levels (mg/kg)
Bangladesh	6	4	2.4 - 17	8.8	4
China	29	20	1.6 - 3900	27	3.3
India	1	0	<1.0	<1.0	<1.0
Indonesia	6	4	3.4 - 34	12	5.4
Italy	1	0	<1.0	<1.0	<1.0
Mexico	1	1	17 000	17 000	17 000
Philippines	2	1	9.2	9.2	4.9
Thailand	8	4	8.7 - 390	29	4.6
Tunisia	2	1	780	780	390
Turkey	3	2	5.6 - 25	15	5.6
USA	4	3	25 - 2000	660	340
Vietnam	7	3	2.5 - 22	6.3	<1.0
Unknown	12	7	1.2 - 480	46	2.1
Total	82	50	1.2 – 17 000	21	3.1

Table 4. The number of samples in which NPEs were identified arranged by country of manufacture, with the NPE concentration range, the median NPE concentrations in all samples, and the median values for those samples in which NPEs were detected, for each country.

Box A. Nonylphenol ethoxylates (NPEs)

Nonylphenol ethoxylates (NPEs) are a group of chemicals used as surfactants, emulsifiers, dispersants and wetting agents in a variety of applications, including the manufacture of textiles. The largest share has been used in industrial and institutional cleaning products (detergents), with smaller amounts used as emulsifiers, textile and leather finishers and as components of pesticides and other agricultural products and water-based paints (OSPAR 2004, Guenther *et al*. 2002). The use of NPEs during the manufacture of textiles can leave residues of NPEs within the final product that are readily released when the items are washed as part of their normal use (Brigden *et al*. 2012, Greenpeace 2012a).

Where NPEs are released, including from textile manufacture facilities or through the laundering of textile products, either directly into surface waters or via wastewater treatment facilities, they can break down to form nonylphenol (NP), a closely-related group of persistent, bioaccumulative and toxic chemicals (OSPAR 2004, Jobling *et al.* 1996).

Both NPEs and NP are widely distributed in fresh and marine waters and, in particular, sediments, in which these persistent compounds accumulate (Fu *et al*. 2008, Shue *et al*. 2010, David *et al*. 2009). Because of their releases to water, NPEs and NP are also common components of sewage effluents and sludge (Micic & Hofmann 2009, Ying *et al*. 2009, Yu *et al*. 2009), including that applied to land. NP has been detected in rain and snow (Fries & Püttmann 2004, Peters *et al*. 2008), and as contaminants in house dust (Butte & Heinzow 2002, Rudel *et al*. 2003) and indoor air (Rudel *et al*. 2003, Saito *et al.* 2004). Research into levels in wildlife remains limited, although there have been reports of significant levels in both invertebrates and fish in the vicinity of sites of manufacture and/or use of NPEs and close to sewer outfalls (Lye *et al*. 1999, Rice *et al*. 2003, Mayer *et al*. 2008). NP is known to accumulate in the tissues of fish and other organisms (OSPAR 2004), including human tissues (Lopez-Espinosa *et al*. 2009). The most widely recognised hazard associated with NP is estrogenic activity, i.e. the ability to mimic natural estrogen hormones. This can lead to altered sexual development in some organisms, most notably the feminisation of fish (Jobling *et al*. 1995, 1996).

The manufacture, use and release of NPEs and nonylphenol are regulated in some countries (OSPAR 1998, EU 2003, CEPA 2004, USEPA 2010) though no such regulations apply in many others. More than 10 years ago, the Ministerial Meeting under the OSPAR Convention agreed on the target of cessation of discharges, emissions and losses of hazardous substances to the marine environment of the northeast Atlantic by 2020, and included NP/NPEs on the first list of chemicals for priority action towards this target (OSPAR 1998). Since then, NP has been included as a ‘priority hazardous substance’ under the EU Water Framework Directive, such that action to prevent releases to water will be required throughout Europe within 20 years of adoption of the regulation (EU 2001). Even before the listing under this Directive, however, the widely recognised environmental hazards presented by NP and NPEs have led to some long-standing restrictions on their use in many countries. Among these, a Recommendation agreed by the Paris Commission (now part of the OSPAR Commission) in 1992 required the phase-out of NPEs from domestic cleaning agents by 1995 and industrial cleaning agents by the year 2000 (PARCOM 1992). Furthermore, within the EU, formulations containing greater than 0.1% NP or NPEs may no longer be placed on the market within Europe after January 2005, with some minor exceptions principally for ‘closed-loop’ industrial systems (EU 2003). Though no regulations addressing manufacture, use and release exist in China, NP and NPEs have recently been included on the ‘List of toxic chemicals severely restricted on the import and export in China’, which requires prior permission for the import or exports of NP or NPEs (MEP 2011). No regulations currently exist that restrict the sale of textile products containing NPE residues, though such a regulation is currently under development within the EU (KEMI 2012).

3.2 Carcinogenic amines released under reducing conditions

Carcinogenic amines were not released under the test conditions at levels above the method detection limit (<5 mg/kg) in any of the 41 articles tested.

Box B. Carcinogenic amines released by certain azo dyes

Azo dyes can undergo reduction to release aromatic amines. Some, though not all, aromatic amines that can be released from azo dyes have been shown to be carcinogenic (IARC 1998, 1987). Azo dyes are manufactured using the same amines that can be later released through reduction, and it is therefore possible for commercial azo dye formulation to contain residues of amines used in their manufacture. Furthermore, certain carcinogenic amines have been detected as residues in other amines that are used for azo dye manufacture, providing an additional route for contamination of commercial azo dye formulations with carcinogenic amines (IARC 2008). These sources could contribute to the presence of carcinogenic amines at trace levels within textile products.

Legislation exists in certain countries, including EU member states and China, which prohibits the sale of products containing dyes that can degrade under specific test conditions to form carcinogenic amines at concentration above set limits, for textile articles which may come into direct and contact with human skin. The EU regulation lists 22 compounds, with a limit of 30 mg/kg (EU 2002). The regulation in China sets a limit of 20 mg/kg and lists the same compounds as the EU regulation, as well as two additional compounds (SAC 2012a).

3.3 Phthalates in plastisol prints

Of the 35 articles for which plastisol printed fabric sections were analysed for phthalates, one or more phthalate was found to be present above the method detection limit (3 mg/kg) in 33 articles. For the other two articles, phthalates were not detected above the method detection limit (<3 mg/kg for individual phthalates) in the plastisol printed section.

For two articles, the printed fabric contained phthalates at a concentration above 1000 mg/kg (0.1% by mass, see Table 5 for details). One of these samples (TX13094), a Primark t-shirt purchased in Germany, contained a particularly high concentration of di-(2-ethylhexyl) phthalate (DEHP), 110 000 mg/kg (11.0%). The other sample (TX13015), a baby one-piece from American Apparel manufactured and purchased in the US, had a lower but still relevant level of another phthalate, di-iso-nonyl phthalate (DINP), at 5900 mg/kg (0.59% by weight). The presence of these phthalates at the concentrations found suggests their use as plasticisers within the plastisol formulations used to manufacture these products.

Of the remaining 31 articles in which phthalates were detected, concentrations for individual phthalates were below 100 mg/kg (0.01%) for all but one article and below 10 mg/kg (0.001%) for 11 of the 31 articles. The two articles in which phthalates were not detected were both t-shirts sold by GAP (TX13050 & TX13057). However, phthalates were detected in the prints of five other t-shirts sold by GAP, with total phthalate concentrations for each article in the range 5.5-42 mg/kg. Full details of the individual phthalate concentrations for all 35 articles are presented in Appendix 2.

For the 31 articles in which individual phthalates were below 1000 mg/kg (0.1%), the concentrations would be too low to be expected to have any significant plasticising function on their own. For these articles, the identified phthalates are more likely present due to contamination of other substances used within the plastisol formulation (including other plasticisers, inks or pigments), or through other uses of the phthalates within the facilities that manufactured the products. In addition, it cannot be excluded that the presence of phthalates at these levels could have arisen from sources unrelated to chemical use at the facilities that manufactured the products, such as through contact with phthalate-bearing materials subsequent to manufacture, up until the point at which the products were purchased and separately sealed for analysis. Nonetheless, the presence of phthalates within a product at any level is of concern, whatever the source.

DEHP is known to exhibit reproductive toxicity, being toxic to the developing reproductive system in mammals (Ema & Miyawaki 2002, Mylchreest *et al*. 2002, Aso *et al*. 2005). Within the EU, DEHP (together with some other phthalates) has been listed as a Substance of Very High Concern (SVHC) under the EU REACH Regulation (ECHA 2013). DINP, though not currently among the phthalates considered to be of greatest regulatory concern, nonetheless does exhibit toxicity (primarily to the liver and kidney) at high doses. In addition, some hormone-disrupting (anti-androgenic) effects on reproductive development in rats have recently been reported for DINP (Boberg *et al*. 2011). Further background information on phthalate esters is provided in Box C, and legislation specific to textile products is discussed in the conclusions.

Phthalates in plastisol formulations are not tightly bound to the plastic, but are present as mobile components within the matrix, and can therefore be released from the product over time (DoE 1991, Jenke *et al*. 2006, Fasano *et al*. 2012, Latorre *et al*. 2012).

Sample code	TX13015	TX13094
Brand	American Apparel	Primark
Sold in	USA	Germany
Made in	USA	unknown
Phthalate – mg/kg (% by mass):		
Di-(2-ethylhexyl) phthalate (DEHP)		110 000 (11%)
Di-isononyl phthalate (DINP)	5900 (0.59%)	

Table 5. Concentrations of individual phthalates (mg/kg) where present in articles above 1000 mg/kg.

Box C. Phthalate esters (Phthalates)

Phthalates (or, more accurately, phthalate diesters) are a group of chemicals with a diversity of uses, dominated by use as plasticisers (or softeners) in plastics, especially PVC. Other applications included uses as components of inks, adhesives, sealants, surface coatings and personal care products. Some phthalates are discrete chemicals, such as the well-known di(2-ethylhexyl) phthalate (DEHP), while others are complex mixtures of isomers, such as diisononyl phthalate (DINP) and diisodecyl phthalate (DIDP). All uses of phthalates, especially the major use as PVC plasticisers, result in large-scale losses to the environment (both indoors and outdoors) during the lifetime of products, and again following disposal, principally because phthalates are not chemically bound but only physically associated to the polymer chains. Phthalates have been found to leach from food packaging materials and contaminate corresponding food products (Fierens *et a*l. 2012, Fasano *et al*. 2012); from tubing material used for drug products manufacturing (Jenke *et al*. 2006) and from PVC blood bags that primarily contained DEHP (Ferri *et al*. 2012). Moreover, it has been shown that bacteria, which may grow on PVC plastics in wet conditions (e.g., shower curtains), may enhance DEHP leaching from plastic (Latorre *et al*. 2012). Thus, phthalates are widely found in the indoor environment, including in air and dust (Langer *et al*. 2010, Otake *et al*. 2001, Butte & Heinzow 2002, Fromme *et al*. 2004) at concentrations that commonly reflect the prevalence of plastics and certain textiles within the rooms sampled (Abb *et al*. 2009). Once plastic products are disposed to municipal landfills, phthalates may continue to leach, finally reaching groundwater (Liu *et al*. 2010).

Phthalates are commonly found in human tissues, including in blood, breast milk and, as metabolites, in urine (Colon *et al*. 2000, Blount *et al*. 2000, Silva *et al*. 2004, Guerranti *et al*. 2012), with reports of significantly higher levels of intake in children (Koch *et al*. 2006). In humans and other animals, they are relatively rapidly metabolised to their monoester forms, but these are frequently more toxic than the parent compound (Dalgaard *et al*. 2001). Substantial concerns exist with regard to the toxicity of phthalates to wildlife and humans. For example, DEHP, one of the most widely used to date, is known to be toxic to reproductive development in mammals, capable (in its monoester form MEHP) of interfering with development of the testes in early life, thought to be mediated through impacts on testosterone synthesis (Howdeshell *et al*. 2008, Lin *et al*. 2008). Even at low doses, exposure to mixtures of phthalates can result in cumulative effects on testicular development in rats (Martino-Andrade *et al*. 2008). In addition, adverse impacts on female reproductive success in adult rats and on development of the young have been reported following exposure to this chemical (Lovekamp-Swan & Davis 2003, Grande *et al*. 2006, Gray *et al*. 2006). A more recent study (Abdul-Ghani *et al*. 2012) has shown that both DEHP and DBP can induce gross malformations, damage to DNA and changes in behavioural development when administered to developing chick embryos. The review of Caldwell (2012) highlights recently discovered impacts of DEHP including chromosomal damage, increased cancer progression and changes in gene expression at increasingly lower concentrations. Both DEHP and DBP are classified as ‘toxic to reproduction’ within Europe. Butylbenzyl phthalate (BBP) and dibutyl phthalate (DBP) have also been reported to exert reproductive toxicity (Ema & Miyawaki 2002, Mylchreest *et al*. 2002, Aso *et al*. 2005). Other research has revealed a correlation between phthalate exposure during pregnancy and decreased ano-genital index (distance from the anus to the genitals) in male children (Swan *et al*. 2005), though it is clearly not possible to establish a cause-effect relationship from such studies. Other commonly used phthalates, including the isomeric forms DINP and DIDP, are of concern because of observed effects on the liver and kidney, albeit at higher doses. DINP has also been found to exhibit anti-androgenic effects on reproductive development of Wistar rats (Boberg *et al*. 2011), though less prominent than DEHP, DBP and BBP; however, further safety evaluation of DINP should be undertaken.

At present, there are relatively few controls on the marketing and use of phthalates, despite their toxicity, the volumes used and their propensity to leach out of products throughout their lifetime. Of the controls which do exist, however, probably the best known is the EU-wide ban on the use of six phthalates in children’s toys and childcare articles, first agreed as an emergency measure in 1999 and inally made permanent in 2005 (EU 2005). Very similar regulation in China has recently been announced that will address the same phthalates in toys sold in China in the coming year. The use of DEHP, as well as di-n-butyl phthalate (DnBP) and benzyl butyl phthalate (BBP), will be prohibited in all toys with a limit of 0.1% by weight, equivalent to 1000 mg/kg, and the use of DINP, di-iodecyl phthalate (DIDP) and di-n-octyl phthalate (DNOP) will be prohibited in such articles if they can be placed in the mouth (SAC 2013). While these address one important exposure route, exposures through other consumer products have so far largely escaped regulation. In China, draft legislation has been proposed that would prohibit the presence of six phthalates, including DEHP and DINP, at concentrations above 0.1% by weight (1000 mg/kg) for the whole article, in clothes sold for babies and young children (under 36 months old) (SAC 2012b). It should be noted, however, that this legislation has not entered into force, and should it do so some details in the draft may change. Within the EU, certain phthalates, including DEHP, DBP, DiBP and BBP, have been listed as Substances of Very High Concern (SVHC) under the EU REACH Regulation (ECHA 2013).

3.4 Organotins

Organotins were quantified in a total of 32 articles, consisting of 21 articles bearing a large plastisol print, five footwear articles and six sports tops. For some articles, those consisting of a mixture of fabrics or print colours, a number of different sub-samples were analysed. One or more organotin compounds were detected in one or more sub-samples from six articles; three of the 21 articles bearing a plastisol print, and three of the five footwear articles. Organotins were not detected in any of the six sportswear articles. Full details of the individual organotin concentrations for all 39 articles are presented in Appendix 3. Each of the three plastisol prints in which organotins were detected included more than one print colour, and therefore a number of sub-samples were analysed in each case (see Appendix 3 for details). As a result, a range of concentrations is given for some articles where organotins were detected in multiple sub-samples. Monobutyltin (MBT) was detected in all three printed articles in the range 0.14-0.48 mg/kg, and dibutyltin (DBT) was also detected in one of these (TX13009) in the range 0.14-0.16 mg/kg. A summary is given in Table 6.

Sample	Brand	Sold in	Made in	MBT (mg/kg)	DBT (mg/kg)	MOT (mg/kg)	DOT (mg/kg)	Total (mg/kg)
Plastisol print								
TX13009	Adidas	Sweden	Thailand	0.22-0.32	0.14-0.16	<0.1	<0.1	0.22-0.48
TX13063	H&M	Poland	Bangladesh	0.16-0.32	<0.1	<0.1	<0.1	<0.1-0.32
TX13102	Puma	Turkey	Bangladesh	0.48	<0.1	<0.1	<0.1	<0.1-0.48
Footwear								
TX13004	Adidas	Hong Kong	Indonesia	<0.1	<0.1	0.26-6.0	0.28-100	0.28-106
TX13097	Puma	China	Indonesia	<0.1	<0.1	0.42-32	0.56-369	<0.1-401
TX13100	Puma	Indonesia	China	<0.1	<0.1	0.26-34	0.18-71	0.44-105

Table 6. Concentrations of individual organotins, and the total concentrations (mg/kg) where detected in sub-samples from each of the articles.

As with the printed articles, a number of sub-samples were analysed for some of the footwear articles (where the article consisted of a mixture of fabrics or colours), including all articles in which organotins were detected. Table 6 gives the range of concentrations for all sub-samples of each of these articles. Organotins were detected in sub-samples from three footwear articles, though different individual organotins were detected in these articles compared to the printed articles. For the footwear articles, the compounds detected were monooctyltin (MOT) in the range 0.26-34 mg/kg and dioctyltin (DOT) in the range 0.18-369 mg/kg. In most cases, the concentration of MOT was higher than that of DOT in each sub-sample, with the exception of synthetic fabric and fabric lining in TX13100. For each of the three footwear articles, a sub-sample of leather contained the highest concentration of organotins for that article, though a sub-sample of synthetic fabric from one article (TX13100) also contained a high level of organotins (see Appendix 3 for details). Overall, far higher concentrations of organotins were detected in the three footwear articles compared to the printed articles. For each of these footwear articles, the highest total value for all sub-samples was in the range 105-401 mg/kg, while the highest total value for all subsamples of each of the three printed articles was in the range 0.32-0.48 mg/kg. In textile products, organotins including mono- and dibutyltin (MBT, DBT) and mono- and dioctyltin (MOT, DOT) are used as stabilisers in PVC, for example within PVC plastisol prints. In some cases, organotin compounds have also been used as biocides in certain types of textile and leather products, including sportswear, socks and footwear (Matthews 1996, RPA 2005, OSPAR 2011). As a result, organotins have been reported in a wide range of textile articles, predominantly in the forms MBT/DBT and MOT/DOT (BEUC 2012, Greenpeace 2004, Greenpeace 2012c, Laursen *et al*. 2003, TNO 2003, TNO 2005). Organotins are known to be toxic at relatively low levels of exposure to a range of organisms, including mammals, with immunotoxicity, impact on development and neurotoxicity in mammalian systems (Kergosien & Rice 1998, Jenkins *et al*. 2004, Tonk *et al*. 2011a&b). While seafood is the predominant source of organotin exposure for the general population, exposure to consumer products that contain them or to dusts in the home may also be significant. More information on organotins is given in Box D, and regulations specific to textile products are discussed in the conclusions.

Box D. Organotins

Organotins are a group of related chemicals, of which by far the best known is tributyltin (TBT), as a result of its widespread use in anti-fouling paints on ships and boats. However, several other organotin compounds are in common use, most notably mono- and dibutyltin (MBT, DBT), mono- and dioctyltin (MOT, DOT) and triphenyltins (TPT). Most abundant in consumer products are MBT and DBT, primarily due to use as stabilisers in PVC products including plastisol prints on textile articles. DOT is used in consumer products, including sportswear articles and footwear (Matthews 1996, OSPAR 2011). In some cases, organotin compounds have been used as biocides in certain types of textile products, including sportswear, socks and footwear (Greenpeace 2012c). Although anti-fouling paints have accounted for the majority of TBT used, historically this compound has also been used as a biocide in some consumer products, including certain textiles and carpets, though regulations prohibiting his use now exist in certain countries (Allsopp *et al.* 2000, 2001, OSPAR 2011).

Organotins have been detected in a wide range of textile articles, predominantly in the forms MBT/DBT and MOT/DOT. For textile articles bearing plastisol prints, various studies have detected MBT (7.2 mg/kg), DBT (0.02-9.7 mg/kg), MOT (0.06 mg/kg), and DOT (1.4 mg/kg) (Laursen *et al*. 2003, TNO 2003, TNO 2005), and total organotins (0.004-0.474 mg/kg) (Greenpeace 2004). Examples have also been reported of sportswear containing DBT (3.2 mg/kg, BEUC 2012), and outdoor clothing containing MBT (2.3 mg/kg), DBT (5.8 mg/kg), MOT (0.55-13 mg/kg), DOT (5.6 mg/kg), and total organotin (1.129 mg/kg) (Greenpeace 2004, Greenpeace 2012c). The widespread use of tributyl tin (TBT) in anti-fouling paints on ships, combined with the relative persistence of butyltins and their affinity for biological tissues, has led to their widespread occurrence in fish, and marine mammals for many years (Kannan *et al*. 1996, Iwata *et al.* 1995, Suominen *et al*. 2011). Organotin residues have also been detected in human livers, predominantly due to seafood consumption (Takahashi *et al*. 1999, Nielsen & Strand 2012, Guérin *et al*. 2007). While the consumption of seafood probably remains the predominant source of organotin exposure for humans, exposure to consumer products that contain them or to dusts in the home may also be significant. Organotins have been detected in the terrestrial environment, though far fewer studies have been carried out compared to the marine environment (Zuliani *et al*. 2010). Organotins are known to be toxic to a range of organisms, including mammals, at relatively low levels of exposure. In marine invertebrates, TBT is generally more toxic than DBT, which is in turn more toxic than MBT (Cima *et al*. 1996). However, this is by no means always the case, as DBT is more toxic than TBT to certain enzyme systems (Bouchard *et al.* 1999, Al-Ghais *et al*. 2000). In fish, DBT is frequently a more potent toxin than TBT (O'Halloran *et al*. 1998), with the immune system the primary target. Organotins have also been found to have immunotoxicity and teratogenic (developmental) properties n mammalian systems (Kergosien & Rice 1998), with DBT again frequently appearing more toxic than TBT (De Santiago & Aguilar-Santelises 1999). DBT is neurotoxic to mammalian brain cells (Eskes *et al*. 1999, Jenkins *et al*. 2004). DBT was also found to cause an increased incidence of cell death (apoptosis) in certain tissues of the brains of rats exposed during development (Jenkins *et al*. 2004). Toxic effects on testes development in mice have also been reported (Kumasaka *et al*. 2002). Immunotoxicity and impacts on developmental in mammals have also been reported for DOT and MOT, including impacts on the thyroid and T-lymphocyte immune response (Tonk *et al*. 2011a, 2011b, Faqi *et al*. 2001).

Until recently, legislative controls on organotin compounds have focused primarily on TBT in anti-fouling paints (IMO 2004). TBT substances are also 'priority hazardous substances' under the EU Water Framework Directive (EU 2001), such that action to prevent releases to water within 20 years will be required throughout Europe. Regulations now exist in certain countries (primarily within the EU) on the presence of organotins in consumer products (EU 2010). Tri-substituted organotin compounds are prohibited in products sold in the EU where the equivalent concentration of tin is above 0.1 % by weight in the article or it parts. In addition, dibutyltin (DBT) compounds are prohibited where the equivalent concentration of tin in an article is above 0.1 % by weight (equivalent to 0.20%, 2000 mg/kg, of DBT), with certain exceptions until 2015, including fabrics coated with PVC containing DBT compounds as stabilisers when intended for outdoor applications. Similarly, dioctyltin (DOT) compounds are prohibited in certain articles where the equivalent concentration of tin is above 0.1 % by weight (equivalent to 0.31%, 3100 mg/kg, of DOT), including textile articles intended to come into contact with the skin, gloves, footwear or part of footwear intended to come into contact with the skin, and childcare articles.

Certain industry standards in the textile sector also set limits for certain organotins in textile products. For example, the Global Organic Textile Standard (GOTS) prohibits MBT above 0.1 mg/kg, and certain other organotins including DBT, TBT and DOT above 0.05 mg/kg (GOTS 2011). Similarly, the Oeko-Tex standard for textiles sets a limit of 1.0 mg/kg for TBT and 2.0 mg/kg for DBT and DOT (Oeko-Tex 2012).

3.5 Per- and polyfluorinated chemicals (PFCs)

PFCs were quantified in 15 articles, consisting of seven waterproof clothing articles, three footwear articles and five swimwear articles. The articles were analysed for a range of per- and polyfluorinated chemicals (PFCs). Two separate analyses were carried out:

(1) analysis for a range of ionic PFC compounds, predominantly perfluorosulfonates (for example, perfluorooctane sulfonate, PFOS) and perfluorinated carboxylic acids (for example, perfluorooctanoic acid, PFOA); and

(2) analysis for a range of volatile PFCs that are used as precursors during manufacturing processes, consisting of certain fluorotelomer alcohols (FTOHs), fluorotelomer acrylates (FTAs) also known as polyfluorinated acrylates, and N-alkyl perfluorosulfonamides.

One or more PFCs were detected in each of the 15 articles. Ionic PFCs were more commonly detected, with examples being found in all but one article. Examples of volatile PFCs were detected in five of the 15 articles (four of the seven waterproof clothing articles and one footwear article). Where volatile PFCs were detected, however, they were generally found in considerably higher concentrations than ionic PFCs. Due to this notable difference between the two broad sub-groups of PFCs (ionic and volatile), the results for each sub-group are discussed separately in the sections below. A summary of the number of articles in which ionic and volatile PFCs were detected is given in Table 7, together with the range and median of the total concentrations of ionic PFCs in the various articles, and the same for volatile PFCs. Details of the concentrations of individual PFCs in all articles, both by mass (μg/kg) and by area (μg/m²), are given in Appendix 4.

			Ionic PFCs			Volatile PFCs		
Article type	No. of samples	PFCs detected in	Detected in	Total conc. range (μg/kg)	Total conc. median (μg/kg)	Detected in	Total conc. range (μg/kg)	Total conc. median (μg/kg)
Waterproof clothing	7	7	6	ND - 2290	18.3	4	ND - 6967	2383
Footwear	3	3	3	2.55 - 25.2	2.69	1	ND - 499	ND
Swimwear	5	5	5	1.39 - 68	3.51	0	ND	ND
Total	15	15	14	ND - 2290	11.7	5	ND-6967	ND

Table 7. Summary of articles in which PFCs were detected, together with a breakdown of the ranges and medians of the total concentrations for each of the ionic PFC and volatile PFC subgroups. ND – not detected.

Ionic PFCs

By far the highest concentration of ionic PFCs for all articles was detected in one portion from waterproof trousers sold by H&M (2290 μg/kg, TX13067a), though the concentration in another portion from the same article was substantially lower (26.4 μg/kg, TX13067b). For the sample with the second highest concentration – Adidas swimwear (TX13006) – both portions contained the same total ionic PFC concentration (68.0 μg/kg, in both TX13006a and TX13006b), more than 30 times lower than the highest recorded value in this study (for TX13067a). Two other waterproof clothing articles contained notable concentrations of ionic PFCs. One portion of an H&M coat (TX13065) had a total ionic PFC concentration of 314 μg/kg, while the value for another portion of the same article was 32.7 μg/kg. A Nike coat (TX13082) had a total ionic PFC concentration of 29.7 μg/kg.With the exception of the one sample with the highest level (TX13067b), the ranges of total ionic PFC concentrations were reasonably similar for the remaining six articles of waterproof clothing, for the three footwear articles, and for the five swimwear articles. The median values for these three sub-groups (excluding TX13067a) were 10.2 μg/kg (waterproof clothing), 2.69 μg/kg (footwear articles) and 3.51 μg/kg (swimwear).

Among the footwear articles, shoes sold by Puma had the highest total ionic PFC concentration (25.2 μg/kg, TX13097), approximately 10 times higher than the total concentration of ionic PFCs in portions from the other two footwear articles (TX13004a & TX13085). For swimwear articles, the highest total ionic PFC concentration was detected in swimwear sold by Adidas (68.0 μg/kg, in both portions TX13006a and TX13006b), over 15 times higher than the total concentration in the next highest swimwear sample (TX13042).

Although differences were seen between levels in individual articles for each type of product, the number of articles in each of the three sub-groups was too few to draw any general conclusions about the variation in levels between the three types of product in general, or between different brands as a whole.There were some notable differences in the composition of ionic PFCs in individual articles, with perfluorosulfonates dominating in five of the 14 articles in which ionic PFCs were detected, while perfluorinated carboxylic acids dominated in the other nine.

Among the waterproof clothing articles, the C-6 sulfonate (perfluorohexane sulfonate, PFHxS) was the predominant ionic PFC for two H&M coats, for each of which one of the samples tested had a notably high total ionic PFC concentration (TX13067 and TX13065), as well as in a sample from a Primark coat (TX13093); with PFHxS making up 81-99% (TX13067a/b), 61-96% (TX13065a/b) and 100% (TX13093) of the totals respectively. For one footwear article, Puma shoes (TX13097), the only ionic PFC detected was the shorter chain C-4 sulfonate, perfluorobutane sulfonate (PFBS). For one swimwear article sold by Burberry (TX13023), the dominant compound was perfluorooctane sulfonate (PFOS), comprising 76% of the total.

Of the five articles in which perfluorosulfonates dominated, two of the clothing articles (TX13067 and TX13065) had portions with the highest ionic PFC concentrations among all clothing articles, and the Puma shoes (TX13097) had the highest total among footwear articles.

Although PFOS was not the main perfluorosulfonate detected in any of the samples, the presence of this compound in three articles is of some significance given the regulations that exist in some countries setting a maximum allowable concentration by area for PFOS in textiles (1 μg/m²) (EU 2006). For none of these three samples, however, was this limit exceeded (0.855 μg/m² in TX13004a, Adidas shoe; 0.464 μg/m² in TX13023, Burberry swimwear; 0.954 μg/m² in TX13065b, H&M coat). Overall, the predominant sulfonate detected was PFHxS, a compound with many similar properties to PFOS, but for which no regulations currently apply to use in textiles.

In contrast, the composition for the remaining eight articles in which ionic PFCs were detected was dominated by perfluorocarboxylic acids, predominantly the C4-acid (perfluorobutanoic acid, PFBA) and the C8-acid (perfluorooctanoic acid, PFOA). PFBA was the dominant ionic PFC for seven samples, contributing between 36% and 100% of the total concentration, and was also detected in another five samples as a more minor component.

PFOA was detected in samples from five articles. By far the highest concentration was found in an Adidas swimwear article (TX13006), with a concentration of 65.8 μg/kg (equivalent to 15.3 μg/m²) in one portion (TX13006a) and 68.8 μg/kg (equivalent to 14.5 μg/m²) in another (TX13006b), both approximately nine times higher than the second highest concentration, a Nike coat (TX13082, 7.40 μg/kg equivalent to 0.518 μg/m²). The Nike coat (TX13082) and one portion from an Adidas coat (TX13003b) also contained longer chain PFCAs, PFDA and PFDoA (TX13082 only). For all articles in which PFOA was detected, the corresponding sulfonate (PFOS) was not detected. Other perfluorinated carboxylic acids (PFPA, PFHxA, PFDA & PFDoA) were detected in one or more articles, predominantly in clothing articles.

Many ionic PFCs, including PFOS, PFOA and other long-chain PFCAs, are highly persistent compounds which can bioaccumulate and exhibit a range of toxic properties, see Box E for details.

Volatile PFCs

In addition to the ionic PFCs described above, volatile PFCs were detected in five of the 15 articles, predominantly in waterproof clothing articles (four of seven clothing articles tested). No volatile PFCs were detected in any of the swimwear articles.

Volatile PFCs were not detected in the sample that had by far the highest concentration of ionic PFCs (TX13067, H&M waterproof trousers), and overall there were no clear patterns between the concentrations of volatile PFCs and those of ionic PFCs for individual articles.

Overall, the predominant volatile PFCs detected were two fluorotelomer alcohols (FTOHs); 8:2 FTOH, with 10:2 FTOH present in lower concentrations. In addition, two fluorotelomer acrylates (FTAs) were detected in the same articles, predominantly 8:2 FTA and with lesser amounts of 10:2 FTA.

Where detected, the total concentration of volatile PFCs was considerably higher than the total concentration of ionic PFCs in the same article (between 51 and 1110 times higher). For clothing articles, total volatile PFC concentrations were in the range 380-6970 μg/kg. The highest total concentration was found in a Nike coat (TX13082, 6970 μg/kg), with two other articles having approximately half this level; an Adidas coat (TX13003, 2420 μg/kg) and a Uniqlo jacket (TX13108, 2350 μg/kg).

Concentrations were lower for the Adidas footwear article (TX13004). The total for volatile PFCs was 499 μg/kg, still considerably higher (by approximately 200 times) than the total ionic PFC concentration in the same sample.

The FTOHs (8:2 FTOH and 10:2 FTOH) and the FTAs (8:2 FTA and 10:2 FTA) can give rise to PFOA and PFDA, respectively (Frömel & Knepper 2010, Butt *et al* . 2013, Young & Mabury 2010), long-chain PFCAs that are highly persistent compounds which can bioaccumulate and exhibit a range of toxic properties (See Box E).

Box E. Per- and polyfluorinated chemicals (PFCs)

Per- and polyfluorinated chemicals (PFCs) are a group of chemicals in which all (perfluorinated), or most (polyfluorinated), of the carbon-hydrogen bonds present in the organic chemical backbone have been replaced by carbon-fluorine bonds, making them highly resistant to chemical, biological and thermal degradation (OECD-UNEP 2013, Buck *et al*. 2011).

PFCs fall into four broad categories; perfluorinated alkyl sulphonates (PFSA), perfluorocarboxylic acids (PFCAs), fluoropolymers (the best known being PTFE, marketed as Teflon and widely used for 'non-stick' cookware) and fluorotelomer alcohols (FTOH) (Dinglasan *et al*. 2004, OECD-UNEP 2013). In this study, analyses were carried out separately on ionic per-fluorinated chemicals include PFSA (for example perfluorooctane sulfonate, PFOS) and (PFCAs) (for example, perfluorooctanoic acid, PFOA), and for volatile poly-fluorinated chemicals that are generally sed as precursors during manufacturing processes, including fluorotelomer alcohols (FTOHs) and fluorotelomer acrylates (FTAs) also known as polyfluorinated acrylates.

PFCs are used in many industrial processes and consumer products due to their unique chemical properties, including textile products, primarily due to their stability and ability to repel both water and oil (OECD-UNEP 2013, Herzke *et al*. 2012).

Various PFCs have uses for textile products, including the direct use of PFSAs or FTOHs, and the use of fluorinated polymers manufactured from FTOHs. Final products can contain residues of FTOH precursors, or FTAs generated as intermediates in the production of fluorinated polymers from FTOHs. Products can also contain residues of PFCAs or PFSAs, including from being unintentional manufacturing by-products or use as process aids in the manufacture of fluorinated polymers (Buck *et al*. 2011, Herzke *et al*. 2012, Poulsen & Jensen 2005).

Despite their widespread use, there is very little information about PFC content in textile products relative to the number of type of products in which PFCs may have been employed during manufacture. Of the few studies that have been reported for textiles, PFCAs, PFSAs and FTOHs have frequently been reported in outdoor clothing and footwear articles and swimwear (SSNC FoEN 2006, Greenpeace 2012c, Herzke *et al*. 2012, Schlummer 2013, Greenpeace 2013b, Greenpeace 2013c)

The manufacture and use of PFCs, including for textiles, can result in releases to the environment, either directly from manufacturing facilities, or indirectly when products containing PFCs are used and disposed of. Precursor PFCs, such as FTOHs, are volatile and can be released from products under ambient conditions (Langer *et al*. 2010, Schlummer *et al*. 2013).

Many PFCs, especially longer-chain PFCAs (including PFHxS, PFOS and PFDA) and PFSAs (including PFHxS and PFOS), are highly persistent and do not readily break down once released to the environment, which has led to their ubiquitous presence in the environment, even in remote regions (Frömel & Knepper 2010, Ahrens 2011, OECD-UNEP 2013). Furthermore, their ability to bioaccumulate has led to many PFCAs and PFSAs being reported in a wide range of both aquatic and terrestrial biota (Giesy *et al.* 2001, Conder *et al.* 2008, Houde *et al.* 2011, Loi *et al.* 2011, Greaves *et al.* 2012). PFSAs and PFCAs, particularly PFOS and PFOA, have been reported in human blood (Fromme *et al.* 2009, Olsen *et al.* 2012) and milk (Tao *et al.* 2008, Liu *et al.* 2010, Thomsen *et al.* 2010) for general populations in many countries around the world. Some studies have reported increasing levels of PFHxS in recent years (Kato *et al.* 2011, Glynn *et al.* 2012). For aquatic organisms, take up is generally from water and contaminated food, whereas for terrestrial organisms exposure is primarily via food and air (OECD-UNEP 2013). Precursor PFCs, such as FTOHs, are volatile and have frequently been detected in air samples, even to remote areas (Weinberg *et al.* 2011, OECD-UNEP 2013).

Fluorotelomer alcohol (FTOHs) can be transformed into PFCAs either through biotransformation (Frömel & Knepper 2010, Butt *et al.* 2013), or abiotically in the atmosphere (Young & Mabury 2010). 8:2 FTOH can give rise to C8 compounds including PFOA, while 6:2 FTOH can result in C6 compounds including PFHxA. Humans occupationally exposed to high levels of 8:2 FTOH have been found to have high concentrations of PFOA in their blood (Nilsson *et al.* 2013). In addition, there are indications that biotransformation can form intermediate products in the body that can be more harmful than the PFCA end product (Rand & Mabury 2012).

Studies indicate that PFCs can cause adverse impacts both during development and during adulthood. PFCs, including PFOA, have been shown to act as hormone (endocrine) disruptors (Jensen and Leffers 2008, White *et al.* 2011, Du *et al.* 2013), and studies have suggested that PFOS and PFOA exhibit reproductive toxicity, including for humans (Fei *et al.* 2009, Joensen *et al.* 2009). Impacts on the immune system have also been reported, (Lau et al. 2007, DeWitt *et al.* 2008, Peden-Adams *et al.* 2008), and some are potentially carcinogenic in animal tests (Andersen *et al.* 2008, Lau *et al.* 2007). In addition, it has been reported that epidemiological studies have shown possible links between elevated blood levels of PFOA in humans has possible links with other diseases, including thyroid diseases, elevated blood pressure and certain cancers (Melzer *et al.* 2010, Grandjean *et al.* 2012, OECD-UNEP 2013).

Information regarding the toxicology of FTOH is scarce, though some studies indicate that 6:2 FTOH and 8:2 FTOH how endocrine-disrupting activity, including disturbing fish reproduction (Liu 2009, Liu 2010, Rosenmai *et al.* 2013). In addition to direct hazards from FTOH, the potential for FTOHs to transform into other PFCs, including PFCAs, poses an additional hazard.

PFOS have been classified as persistent organic pollutants (POPs) under the Stockholm Convention, a global treaty to protect human health and the environment, requiring contracting parties to take measures to restrict the production and use of PFOS, although a wide range of uses are currently exempted (UNEP 2009). Within the EU, the marketing and use of PFOS has been prohibited for certain uses since 2008, although many similar exemptions exist to those under the Stockholm Convention (EU 2006).

In some countries there are regulations related to textile products. Within the EU a maximum limit of 1 $\mu g/m^2$ is set for PFOS in textiles (EU 2006). Even where regulation of PFOS in textile products is in place, no such limits are currently in place for any other PFCs, despite concerns for their hazardous nature and the fact that they can commonly be found at far higher concentrations in textiles. The one exception is that the sale of textiles containing PFOA above 1 $\mu g/m^2$ will be prohibited in Norway from June 2014 (NME 2013). In addition, PFOA and four other long-chain PFCAs (PFUnA, PFDoA, PFTrA, PFTeA) are also classified as substances of very high concern (SVHCs) within the EU under the REACH regulations (ECHA 2013), and certain long-chain PFCAs (PFNA, PFDA, PFUnA, PFDoA, PFTrA, PFTeA) have recently been added to a list of priority chemicals in Norway, meaning that releases to the environment must be eliminated or substantially reduced by 2020 (NEA 2013).

3.6 Antimony

Antimony was quantified in sub-samples from the 36 articles that included fabrics composed of polyester, or a blend of polyester and other fibres. Where the fabric was reported to be 100% polyester, the antimony concentration was determined directly. Where the fabric was reported to be composed of a blend of polyester and other fibres, the concentration of antimony was determined within the fabric blend and the concentration in the polyester fraction was calculated on the basis that all antimony arose from the polyester fibre within the fabric blend.

Antimony was detected in all 36 articles, with concentrations in the fabric blends in the range 14-293 mg/kg of polyester (median = 96 mg/kg). The concentrations of antimony within the polyester fraction of each fabric (calculated from the fabric composition information) were also in the range 14-293 mg antimony/kg polyester, though with a higher median (120 mg/kg). Details of antimony concentrations in individual articles are presented in Appendix 1. The range of concentrations is consistent with reports that commercial polyester fibres typically contain up to 300 mg/kg antimony (Duh 2002, Lacasse & Baumann 2004).

Other than for two brands (Adidas and Nike), only three or fewer articles from each brand were analysed for antimony in polyester, too few to draw any conclusion. For the two brands for which more articles were analysed, a wide range of concentrations was found for the articles from each brand. For Adidas (8 articles), the concentrations of antimony in the polyester fraction were in the range 46-293 mg/kg polyester (median = 160 mg/kg), while for Nike (5 articles), concentrations were in the range 14-119 mg/kg polyester (median = 73 mg/kg). For each of these two brands, the range of concentrations in the polyester fraction was similar to that for the 36 articles as a whole (see Table 8).

Brand	No. of samples	No. in which antimony detected	Antimony conc. in polyester (mg/kg)	Median in polyester (mg/kg)
Adidas	10	10	46 - 293	160
Nike	5	5	14 - 119	73
All other brands*	21	21	42 - 217	126
Total	36	36	14 - 293	120

Table 8. Detection of antimony, by brand, in the polyester fraction of the fibre blend, with concentrations calculated on the basis that all antimony arose from the polyester fibre within the fabric blend.
* *Three or fewer articles were analysed from each of these brands.*

A compound of antimony (antimony trioxide, Sb2O3) is commonly used as a catalyst in the manufacture of PET, the predominant polyester polymer (Jaffe & East 2007, Thiele 2004), resulting in polyester fibres containing residues of antimony trioxide (Duh 2002, Lacasse & Baumann 2004). Antimony can also be releases in wastewaters from facilities manufacturing textiles from polyester fabrics or fibres (Greenpeace 2013a)

Trivalent antimony, such as is present in antimony trioxide, is a more toxic form of antimony compounds, with effects including dermatitis, irritation of the respiratory tract and interference with the immune system (Kim *et al.* 1999). In addition, antimony trioxide is listed by the International Agency for Research on Cancer (IARC) as ‘possibly carcinogenic to humans’ (group 2B), principally due to inhalation of dusts and vapours (IARC 1989), and antimony trioxide has been classified under the Globally Harmonised System of Classification and Labelling of Chemicals (GHS) as suspected of causing cancer (H351). Inhalation exposure to antimony is more common in occupational settings, whereas the general population is exposed to antimony mainly through ingestion of food and water. More information on antimony, particularly antimony trioxide, is given in Box F.

Box F. Antimony

Antimony trioxide (Sb2O3) is commonly used as part of the polymerisation process used to produce polyethylene terephthalate (PET) (Jaffe & East 2007, Thiele 2004). The term ‘polyester’ refers to a chemical class (group) of polymers rather than a single plastic, and of these PET is of the greatest significance, accounting for the bulk of production. Antimony trioxide has other industrial uses, including as a component of flame retardant formulations, some of which are used in certain textile products, though usually not in clothing products (Lau *et al*. 2003). Antimony trioxide is the preferred catalyst for PET production due to a balance of cost, catalytic ability and colour of the produced polymer. Alternatives exist, mainly based on titanium compounds, and are reported to be in use, albeit limited compared to antimony trioxide. Certain alternatives exhibit a higher catalytic activity than antimony trioxide, but are generally more expensive and some can produce colour tinted polymer (Thiele 2004, Pang *et al*. 2006). Polyester produced with one titanium-based catalyst has been reported to be able to be dyed at lower temperatures in a shorter time and with a lower dyestuff concentration compared to that produced with antimony trioxide (Thier-Grebe 2000).

Polyester textile fibres have a very large surface area and are often subjected to harsh conditions during manufacturing processes that can employ wet treatments, high temperatures, and chemical attack. As a result, antimony catalyst within the fibre can leach out into processing water and be released in wastewaters. (Lacasse & Baumann 2004). High levels of antimony were recently reported by Greenpeace in wastewaters discharged from a textile manufacturing facility employing polyester in Indonesia (Greenpeace 2013a). Polyester fabrics contain residues of antimony trioxide used in their manufacture, with commercial polyester fibres typically containing up to 300 mg/kg antimony (Duh 2002, Lacasse & Baumann 2004). Residues of antimony have also been reported in clothing articles containing polyester fibres, with concentrations in the range 1 - 200 mg/kg (Laursen *et al*. 2003, Greenpeace 2012c, Kemi 2013).

Antimony shows many similarities in its chemistry and toxicity to arsenic (Andrewes *et al*. 2004, Patterson *et al*. 2003). However, unlike arsenic, there are relatively few studies concerning the toxicity and ecotoxicity of antimony and its compounds. Those studies that are available indicate that the toxicity of antimony depends greatly on its particular form (i.e. its oxidation state). Trivalent antimony, such as is present in antimony trioxide, is the more toxic state whereas its pentavalent form is far less toxic (Patterson *et al*. 2003, De Boeck *et al*. 2003).

One trivalent compound, antimony chloride, has been reported to have high estrogenicity *in vitro* (Choe *et al*. 2003), suggesting that trivalent antimony may have the potential to be disruptive to the estrogenic system. Antimony compounds have been associated with dermatitis and irritation of the respiratory tract, as well as interfering with normal function of the immune system (Kim *et al*. 1999). Where released to the aquatic environment, toxicity has been reported for a range of aquatic organisms (Nam *et al*. 2009 and references therein). Some organic antimony compounds (including trimethylstibine) are very toxic (Andrewes *et al*. 2004). There is evidence for the formation of organic antimony compounds following the disposal of antimony containing wastes to landfill (Andrewes *et al*. 2004, Filella *et al*. 2002). Also, there is some evidence that inorganic antimony compounds, if ingested, can be converted to organic compounds or reduced to the more toxic trivalent forms in the body (Andrewes *et al*. 2004). In addition, antimony trioxide is listed by the International Agency for Research on Cancer (IARC) as ‘possibly carcinogenic to humans’ (group 2B), with inhalation of dusts and vapours the critical route of exposure (IARC 1989). The assessment found sufficient evidence for the carcinogenicity of antimony trioxide in experimental animals, though there is inadequate evidence in humans due to human carcinogenicity data being difficult to evaluate given the frequent co-exposure to both antimony and arsenic. Subsequent epidemiological studies have investigated increased cancer incidence in humans through occupational exposure (smelter workers), though again observed increase in cancer mortality may have been influenced by co-exposure to arsenic (Schnorr *et al*. 1995). Antimony trioxide has been classified under the Globally Harmonised System of Classification and Labelling of Chemicals (GHS) as suspected of causing cancer (H351). Inhalation exposure to antimony is more common in occupational settings, where as the general population is exposed to antimony mainly through ingestion of food and water. A previous study that found similar levels of antimony in polyester as those in the current study made the assessment that antimony at the levels found did not pose a direct risk to the wearer, due to leaching of antimony compounds into saliva or sweat (Laursen *et al*. 2003)

No regulations currently exist that prohibit use in textile manufacture, despite the availability of alternative catalysts for polyester manufacture. Within the EU, the Ecolabel Regulation, which aims to promote products with a reduced environmental impact compared with other products in the same product group, requires that the antimony content in polyester fibres does not exceed 260 mg/kg for articles bearing the Ecolabel (EC 2009).

4. Conclusions

This study has demonstrated the presence of a number of different hazardous chemicals within a broad range of textile products of the type included in this study, as either components of materials incorporated within the product or residues remaining from use within manufacturing processes.

Among these, the most commonly detected substances were NPEs, with residues identified in products across all brands and almost all countries of manufacture and countries of sale included in the study, indicating that the use of NPEs is widespread within the international textile industry, including within supply chains used by several major international clothing brands.

The fraction of articles in which NPEs were detected (61% of 82 articles) is consistent with those from the two previous studies, in which NPEs were detected in 67% of 78 articles (Brigden *et al.* 2012, Greenpeace 2011a) and 63% of 141 articles (Greenpeace 2012a) respectively, with a similar distribution of concentrations across the articles in this and those from the previous two studies.

NPE concentration range (mg/kg)	Current study: % of samples (of 82 analysed)	Previous study (a): % of samples (of 78 analysed)	Previous study (b): % of samples (of 141 analysed)
<1	39	33	37
1 – 10	25	22	19
>10 – 100	27	27	24
>100 – 1 000	6	15	11
>1 000	4	3	9

Table 9. The number and percentage of samples (of the 82 articles tested) within various NPE concentration ranges, compared to two previous studies (a) Brigden et al. 2012, Greenpeace 2011a; (b) Greenpeace 2012a

In the current study, NPEs were detected in at least one article from all brands, and in one or more articles from 10 of the 12 countries of manufacture. For the other two manufacturing countries, only one article was analysed per country, too few to draw any conclusions about articles manufactured in that country in general.

The presence of NPEs in finished products indicates their use during manufacture, which can result in releases of NPEs and nonylphenol from manufacturing facilities. In addition, NPE residues within textile products are readily released when the items are washed as part of their normal use (Brigden *et al*. 2012, Greenpeace 2012b).

The use of NPEs and nonylphenol during textile manufacture has effectively been banned within the EU (EU 2003), with similar restrictions in place in the US and Canada (CEPA 2004, USEPA 2010). No regulations currently exist that restrict the sale of textile products containing NPE residues, though such a regulation is currently under development within the EU (KEMI 2012). In order to offer adequate protection, such regulations will need to set any limit for NPEs in products as low as possible and cover as wide a range of NPEs as possible.

In addition to the presence of NPEs, the identification of phthalates at high concentrations in two of the articles tested indicates the ongoing use of phthalates as plasticisers in some formulations used to produce plastisol prints on textile products. In addition, the presence of lower levels of phthalates in many other articles illustrates the widespread distribution of these chemicals as ingredients and/or contaminants in industrial processes

The levels and types of individual phthalates found in printed sections from the two articles with high concentrations (see Table 5) are consistent with previous investigations of related textile products, though even higher concentrations have been reported in printed sections from some articles analysed in previous studies (with examples containing individual phthalates at concentrations up to 32% by mass) (RAPEX 2012, Greenpeace 2004, Greenpeace 2012a).

The sale of textiles products containing phthalates, including as components of plastisol prints, is not currently regulated in the countries where the items were sold. However, draft legislation has been proposed in China that would prohibit the presence of six phthalates, including DEHP and DINP, at concentrations above 0.1% by weight (1000 mg/kg) in the whole article, for clothes sold for babies and young children (under 36 months old) (SAC 2012b). It should be noted, however, that this legislation has not entered into force, and should it do so some details in the draft may change. The phthalate data presented in the current study are for sections of printed fabric rather than the whole article.

Regulations do exist in some countries that prohibit certain phthalates (including those identified in this study) in other consumer products, primarily toys, including within the EU (EU 2005) and China (SAC 2013). While such regulations and initiatives do not relate directly to clothing articles, they do recognise the hazard associated with products containing phthalates, including plastic parts containing phthalates as plasticisers.

The predominant organotins among the articles tested were MOT and DOT, identified exclusively in footwear articles. In addition, MBT and DBT were identified in printed fabric sections from three articles, though generally at far lower concentrations.

The concentrations of MOT (0.26-34 mg/kg) and DOT (0.18-369 mg/kg) were generally higher than concentrations previously reported in textile articles (0.06-13 mg/kg and 1.4-5.6 mg/kg, for MOT and DOT respectively), though these previous studies investigated clothing articles rather than footwear (Laursen *et al*. 2003, TNO 2003, TNO 2005, Greenpeace 2012c).

Concentrations of MBT (0.16-0.48 mg/kg) and DBT (0.14-0.16 mg/kg) in printed fabric sections were more consistent with previous reports, with levels somewhat lower than in previous studies, which reported these chemicals in the ranges 2.3-7.2 mg/kg for MBT and 0.02-9.7 mg/kg for DBT (Laursen *et al*. 2003, TNO 2005, Greenpeace 2012c).

Although regulation for consumer products sold in the EU, including certain textile products, prohibits DBT and DOT above certain levels (1000 mg/kg by weight of tin), none of the tested articles had concentrations above the EU limits, including those articles sold outside the EU. However, for all articles in which organotins were detected, the concentrations exceeded limits for certain materials as set by some textile industry standards. The Global Organic Textile Standard (GOTS) prohibits DBT and DOT above 0.05 mg/kg and MBT above 0.1 mg/kg in textiles (GOTS 2011) while the Oeko-Tex standard for textiles sets a limit of 2.0 mg/kg for DBT and DOT for individual materials (Oeko-Tex 2012).

For many of the outdoor clothing articles (4 of 7 items tested), the composition of PFCs was dominated by two fluorotelomer alcohols, 8:2 FTOH and to a lesser extent 10:2 FTOH. Where detected, the concentrations of FTOHs were similar to those reported in previous studies of outdoor clothing and related waterproof textiles (SSNC FoEN 2006, Greenpeace 2012c, Herzke *et al*. 2012, Schlummer 2013). Other volatile PFCs detected in some articles, the fluorotelomer acrylates 8:2 FTA and to a lesser extent 10:2 FTA, were also present at concentrations that were consistent with the limited previous data reported for these compounds in outdoor clothing (Greenpeace 2012c).

This pattern, however, was not universal for all waterproof clothing articles. Volatile PFCs, including FTOHs, were not detected in three articles, all of which contained detectable levels of ionic PFCs, including the article from which one portion had by far the highest concentration of ionic PFCs (TX13067a, H&M waterproof trousers).

Where detected, the ranges of concentrations of many ionic PFCs were quite different to those previously reported in these types of articles (SSNC FoEN 2006, Greenpeace 2012c, Herzke *et al*. 2012). The PFCAs, including PFHxA, PFOA, and PFDA, were found at levels considerably lower than those previously reported, though PFBA concentrations were generally consistent with previous data. In contrast, for the three articles in which it was detected, concentrations of PFHxS were considerably higher than those in previous reports (SSNC FoEN 2006, Greenpeace 2012c), including one sampled section (H&M waterproof trousers, TX13067a) that contained PFHxS many hundreds of times higher than any level in these previous studies (SSNC FoEN 2006, Greenpeace 2012c), though the concentration of PFHxS was considerably lower in another portion drawn from the same article (TX13067b).

The range of PFCs detected in the footwear articles was similar to that previously reported for leather footwear (Herzke *et al*. 2012), though this study only analysed a single sample. As in the current study, FTOHs (8:2 FTOH and 10:2 FTOH) were found to dominate, with similar concentrations in both studies. For ionic PFCs, in some instances higher concentrations were found in the current study (PFBS), while for other the concentrations were considerably lower (PFOS).

For swimwear, the concentrations of PFOA were reasonably similar to the findings of the single previous study of five swimwear articles, though the highest concentrations in the current study (TX13006a/b) were over three times that of the highest concentration we have previously reported (Greenpeace 2013b). The two other PFCs detected in swimwear, PFOS and PFBA, were not detected in the previous study of swimwear, which employed similar detection limits. As with the current study, volatile PFCs, including FTOHs, were not detected in the previous study (Greenpeace 2013b).

In some countries there are regulations related to textile products. Within the EU a maximum limit of 1 $\mu g/m^2$ is set for PFOS in textiles (EU 2006). Even where regulation of PFOS in textile products is in place, no such limits are currently in place for any other PFCs despite concerns for their hazardous nature and the fact that they can commonly be found at far higher concentrations in textiles. The one exception is that the sale of textiles containing PFOA above 1 $\mu g/m^2$ will be prohibited in Norway from June 2014 (NME 2013). In addition, PFOA and four other long-chain PFCAs (PFUnA, PFDoA, PFTrA, PFTeA) are also classified as substances of very high concern (SVHCs) within the EU under the REACH regulations (ECHA 2013), and certain long-chain PFCAs (PFNA, PFDA, PFUnA, PFDoA, PFTrA, PFTeA) have recently been added to a list of priority chemicals in Norway, meaning that releases to the environment must be eliminated or substantially reduced by 2020 (NEA 2013).

PFOS was detected in samples from three articles (Adidas shoe TX13004a, Burberry swimwear TX13023, H&M coat TX13065b), though in all these cases the concentrations were below 1 $\mu g/m^2$. Of these, the Burberry swimwear (TX13023) and the H&M coat were sold in the EU.

In this study, PFHxS was the predominant sulfonate detected, a compound with many similar properties to PFOS in terms of persistence and the potential to bioaccumulate, and for which some studies have reported increasing levels in humans in recent years (Kato *et al.* 2011, Glynn *et al*. 2012, Wang *et al*. 2013). Although the EU regulatory limit for PFOS clearly does not apply to PFHxS, it does provide a useful comparison for concentrations of this compound. The H&M waterproof trousers for which one portion had the highest ionic PFC concentration recorded in this study (TX13067a), the concentration of PFHxS by area was 542 $\mu g/m^2$, far higher than the EU regulatory limit for the related compound PFOS. However, another portion from the same article (TX13067b) had a lower ionic PFC concentration, and therefore a lower concentration of PFHxS by area (4.21 $\mu g/m^2$). PFHxS was also detected in two other articles, two portions from a H&M coat (TX13065a, 4.20 $\mu g/m^2$ & TX13065b, 64.2 $\mu g/m^2$) and a Primark coat (TX13093, 0.170 $\mu g/m^2$). These three articles were all sold in the EU.

PFOA also has some similar properties to PFOS and, as for PFHxS, though the regulatory limit for PFOS (1 $\mu g/m^2$) clearly does not apply to PFOA it does provide a useful comparison for concentrations in textile articles. Though not directly applicable to any articles included in this study, the sale of textiles containing PFOA above 1 $\mu g/m^2$ will be prohibited in Norway from June 2014 (NME 2013). In terms of concentration of PFOA per unit area, the highest levels found were in two samples of Adidas swimwear (TX13006a/b), 14.5-15.3 $\mu g/m^2$, considerably higher than the Norwegian limit for PFOA, or the EU regulatory limit for the related compound PFOS. For all other articles where PFOA was detected, concentrations by area were below 1 $\mu g/m^2$.

Other long-chain PFCAs (PFDA & PFDoA) were also detected, in a Nike coat sold in Argentina (TX13082) and one sample from an Adidas coat (TX13003b, PFDA only). Of these, one (PFDoA) is classified as a substance of very high concern (SVHCs) within the EU under the REACH regulations (ECHA 2013), while both are priority chemicals in Norway requiring that releases to the environment are eliminated or substantially reduced by 2020 (NEA 2013).

Our investigations have shown concentrations of ionic PFCs can vary widely not only between products but also within different parts of the same product. Quality control checks confirm that differences in PFC levels measured for different parts, for each of the five articles tested in duplicate, reflect real variations in concentrations within each of the articles, and do not result from the testing method itself. The determination of concentrations for different portions of the same article was carried out for five articles that were representative of the types of articles analysed for PFCs in this study. The five articles were from certain brands and did not include examples from all brands for which PFCs were detected in articles. Nevertheless, the reported variations are likely not only to be a reflection on the products sold by those brands alone, but rather a characteristic of textile products treated with PFCs in general, and therefore an issue for all brands using PFCs in the manufacture of their products. The full extent of such variations, and the underlying causes, deserve further investigation.

The range of concentrations of antimony in polyester found in this study is consistent with levels reported in commercial polyester fibres (typically up to 300 mg/kg) (Duh 2002, Lacasse & Baumann 2004) and in clothing articles containing polyester fibres (in the range 1 - 200 mg/kg) (Laursen et al. 2003, Greenpeace 2012c, Kemi 2013).

Despite known and suspected toxicity for antimony trioxide, no regulations currently exist that prohibit use in textile manufacture, despite the availability of alternative catalysts for polyester manufacture. Within the EU, the Ecolabel Regulation, which aims to promote products with a reduced environmental impact compared with other products in the same product group, requires that the antimony content in polyester fibres does not exceed 260 mg/kg for articles bearing the Ecolabel (EC 2009). For those fabrics analysed in the current study, antimony concentrations were below 260 mg/kg for all but one sample (TX13011, 293 mg/kg).

In this study, no carcinogenic amines released under certain reducing conditions were detected in any of the samples investigated. Previous studies of textile products have, however, reported the detection of carcinogenic amines (JRC 2008, Laursen *et al*. 2003, Greenpeace 2012a), indicating their relevance for some textile products, though carcinogenic amines have generally been identified for a relatively low fraction of items tested.

Overall, this study has provided additional understanding of the presence and concentrations of a broad range of chemicals within high street fashion textile products, across a diverse range of brands and countries of manufacture and sale. The use of these and other hazardous chemicals during manufacture can be expected to result in releases from manufacturing facilities, including within wastewaters, in addition to the presence of chemical residues in the products themselves. In addition, there is the potential for losses of hazardous chemicals within the textile products following their sale, either directly such as in the case of phthalates within plastisol prints (Jenke *et al*. 2006, Fasano *et al*. 2012, Latorre *et al*. 2012), or when washed as part of their normal use, most notably for NPEs (Brigden *et al*. 2012, Greenpeace 2012b).

Despite the scale of this study, the number of articles investigated is, if course, inevitably small compared to the vast number of products manufactured and sold per country or per brand. It cannot, therefore, be assumed that the results obtained in this study are representative of levels or presence of the chemicals investigated that may be expected for all such products. Rather, this study provides a snapshot of what appears to be a more generic problem that is not restricted to any particular country, product type or brand, and one that deserves further investigation including from a regulatory and brand policy perspective.

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Appendix 1. Concentrations of NPEs, carcinogenic amines, phthalates, organo tins, ionic PFCs, volatile PFCs and antimony in all articles tested

Sample code	Brand	Place of sale	Country of manufacture	Type of product	Fabric	NPEs (mg/kg)	amines (mg/kg)	phthalate total (mg/kg)	Organotin total (mg/kg)	Ionic PFCs (µg/kg)	Volatile PFCs (µg/kg)	Antimony in fabric (mg/kg)	Antimony polyester (mg/kg)*
TX13001	Adidas	Hungary	Thailand	trousers & pullover set	70% cotton, 30% polyester	8.7	<5	-	-	-	-	62	208
TX13002	Adidas	China	China	t-shirt	70% cotton, 30% polyester	<1.0	-	44	<0.1	-	-	55	184
TX13003	Adidas	Taiwan	China	coat	shell 100% polyester; lining 65% polyester, 35% coton	1.8	<5	-	-	2.18-10.2	2420	105	105
TX13004	Adidas	Hong Kong	Indonesia	shoes	upper coated leather; lining textile; outer sole rubber	16	-	-	0.28 - 106	ND-2.55	499	-	-
TX13005	Adidas	Columbia	China	football shirt	100% polyester	<1.0	<5	50	<0.1	-	-	49	49
TX13006	Adidas	Germany	China	swimwear	shell 80% nylon, 20% elastane; lining 100% polyester	<1.0	-	12	-	68.0-68.0	ND	100	100
TX13007	Adidas	Indonesia	Thailand	t-shirt	100% polyester	<1.0	<5	54	-	-	-	197	197
TX13008	Adidas	Israel	Indonesia	top	100% polyester	<1.0	-	-	-	-	-	46	46
TX13009	Adidas	Sweden	Thailand	t-shirt	60% cotton, 40% polyester	19	-	21	0.22 - 0.48	-	-	97	242
TX13010	Adidas	Philippines	Thailand	t-shirt	60% cotton, 40% polyester	38	-	45	-	-	-	54	135
TX13011	Adidas	Russia	China	swimsuit	shell 80% nylon, 20% elastane; lining 100% polyester	<1.0	<5	-	-	-	-	293	293
TX13012	American Apparel	China	USA	leggings	80% nylon, 20% elastane	<1.0	-	-	-	-	-	-	-
TX13013	American Apparel	Japan	USA	baby body suit	100% cotton	25	-	-	-	-	-	-	-
TX13014	American Apparel	UK	USA	sweatshirt	50% cotton, 50% polyester	660	<5	-	-	-	-	99	197
TX13015	American Apparel	USA	USA	baby one-piece	100% cotton	2000	-	6100	-	-	-	-	-
TX13016	Burberry	Austria	Tunisia	swimsuit	80% polyamide (nylon), 20% elastane; lining 100% polyamide (nylon)	<1.0	<5	-	-	1.39	ND	-	-
TX13017	Burberry	China	China	t-shirt	100% cotton	54	-	11	-	-	-	-	-
TX13018	Burberry	Taiwan	China	camise	100% cotton	27	-	-	-	-	-	-	-
TX13019	Burberry	Hong Kong	Thailand	jacket	Shell 100% polyester; lining 100% cotton	390	<5	-	-	-	-	47	47
TX13020	Burberry	Turkey	China	t- shirt	80% cotton, 15% nylon, 5% wool	62	-	-	-	-	-	-	-
TX13021	Burberry	Sweden	Thailand	baby body suit	97% cotton, 3% elestane	<1.0	<5	-	-	-	-	-	-
TX13022	Burberry	Spain	China	t-shirt	100% cotton	33	-	-	-	-	-	-	-
TX13023	Burberry	UK	Italy	swimsuit	80% polyamide, 20% elastane; lining 100% polyamide	<1.0	-	-	-	2.76	ND	-	-
TX13024	no article	-	-	-	-	-	-	-	-	-	-	-	-
TX13025	Burberry	UK	Tunisia	shirt	100% cotton	780	-	-	-	-	-	-	-
TX13026	C&A	Hungary	unknown	jacket	96% polyester, 4% elastane	46	-	-	-	7.40	380	91	94
TX13027	C&A	Poland	unknown	t-shirt	100% cotton	<1.0	<5	-	-	-	-	-	-
TX13028	C&A	China	India	baby onesie	100% cotton	<1.0	<5	15	-	-	-	-	-

TX13029	C&A	Turkey	unknown	t-shirt	100% cotton	<1.0	<5	15	<0.1	-	-	-	-
TX13030	C&A	Mexico	Mexico	shoes	Bovine leather, pig skin lining and synthetic outer soles	17 000	<5	-	<0.1	-	-	-	-
TX13031	C&A	Spain	unknown	t-shirt	100% cotton	<1.0	-	130	-	-	-	-	-
TX13032	C&A	Switzerland	unknown	baby t-shirt	100% organic cotton	2.9	-	72	-	-	-	-	-
TX13040	Disney	China	China	dress	94.4% cotton, 5.6% elastane	3900	-	63	<0.1	-	-	-	-
TX13041	Disney	Hong Kong	China	fleece jacket	100% polyester	30	<5	-	-	-	-	107	107
TX13042	Disney	Spain	China	swimsuit	100% polyester	70	-	-	-	4.26	ND	167	167
TX13043	Disney	Thailand	Thailand	t-shirt	100% cotton	<1.0	-	6.0	<0.1	-	-	-	-
TX13044	Disney	USA	China	t-shirt	100% organic cotton	1.6	-	27	<0.1	-	-	-	-
TX13048	GAP	Hong Kong	China	t-shirt	100% cotton	2.5	<5	14	<0.1	-	-	-	-
TX13049	GAP	Columbia	Indonesia	t-shirt	100% cotton	3.4	<5	-	-	-	-	-	-
TX13050	GAP	Greece	Vietnam	t-shirt	100% cotton	<1.0	-	<3.0	<0.1	-	-	-	-
TX13051	GAP	Indonesia	Phillippines	t-shirt	100% cotton	9.2	-	42	<0.1	-	-	-	-
TX13052	GAP	Japan	Indonesia	short pants	not specified	34	-	-	-	-	-	-	-
TX13053	GAP	Israel	Turkey	t-shirt	100% cotton	<1.0	-	26	<0.1	-	-	-	-
TX13054	GAP	Turkey	China	swimsuit	shell 80% nylon, 20% elastane; lining 100% polyester	<1.0	<5	-	-	-	-	128	128
TX13055	GAP	Mexico	Vietnam	t-shirt	100% cotton	<1.0	-	5.5	<0.1	-	-	-	-
TX13056	GAP	Philippines	Vietnam	t-shirt	100% cotton	<1.0	<5	5.6	<0.1	-	-	-	-
TX13057	GAP	Thailand	Philippines	t-shirt	60% cotton, 40% polyester	<1.0	-	<3.0	<0.1	-	-	59	147
TX13058	GAP	USA	unknown	t-shirt	100% cotton	<1.0	-	-	-	-	-	-	-
TX13063	H&M	Poland	Bangladesh	t-shirt	100% cotton	<1.0	<5	7.6	0.16-0.32	-	-	-	-
TX13064	H&M	China	Bangladesh	dress	100% cotton	12	-	45	-	-	-	-	-
TX13065	H&M	Germany	China	coat	Shell 100% polyester; coating 100% polyurethane	7.8	<5	-	-	32.7-314	ND	42	42
TX13066	H&M	Greece	China	t-shirt	100% polyester	38	<5	19	-	-	-	149	149
TX13067	H&M	Sweden	China	plastic pants	100% polyester	89	<5	-	-	26.4-2290	ND	71	71
TX13068	H&M	Spain	China	bodysuit	100% cotton	7.9	-	-	-	-	-	-	-
TX13069	H&M	Thailand	China	sweater	100% acrylic	1.7	<5	27	<0.1	-	-	-	-
TX13072	Li Ning	Germany	China	sports shirt	88% polyester, 12% elastane	2.1	<5	-	<0.1	-	-	70	80
TX13073	Li-Ning	China	China	sports top & shorts	100% polyester	3.3	<5	7.3	<0.1	-	-	121	121
TX13074	Li-Ning	China	China	t-shirt	100% cotton	<1.0	<5	9.5	-	-	-	-	-
TX13075	Li-Ning	China	China	dress	body lining 100% cotton; outershell 60% polyester, 40% nylon	5.1	-	-	-	-	-	-	-
TX13082	Nike	Argentina	Bangladesh	coat	body 100% polyester; lining 65% polyester, 35% cotton	2.4	-	15	-	29.7	6967	14	14
TX13083	Nike	Chile	China	t-shirt	100% cotton	<1.0	<5	31	<0.1	-	-	-	-
TX13084	Nike	Taiwan	China	t-shirt	100% cotton	<1.0	<5	-	<0.1	-	-	-	-
TX13085	Nike	Germany	Vietnam	shoes	Suede, leather and nubuck	6.3	<5	-	<0.1	2.83	ND	-	-

TX13086	Nike	Indonesia	Indonesia	t-shirt	100% polyester	<1.0	<5	-	-	-	-	119	119
TX13087	Nike	Israel	Vietnam	running top	100% polyester	2.5	<5	-	<0.1	-	-	64	64
TX13088	Nike	Turkey	Turkey	t-shirt	100% cotton	5.6	<5	65	-	-	-	-	-
TX13089	Nike	Sweden	Thailand	t-shirt	100% polyester	<1.0	-	-	-	-	-	73	73
TX13090	Nike	Switzerlan d	Vietnam	wind jacket	body 100% nylon; lining: 100% polyester	22	<5	-	-	-	-	104	104
TX13091	Primark	Austria	unknown	swimming trunks	Outer hhell 80% nylon, 20% elastane; lining 100% polyester	480	-	-	-	2.01	ND	134	134
TX13092	Primark	Austria	unknown	sweatshirt	Shell 80% cotton, 20% polyester; lining 65% polyester, 35% cotton	12	<5	11	<0.1	-	-	121	186
TX13093	Primark	Austria	unknown	coat	100% nylon; lining 100% nylon	<1.0	-	-	-	2.43	ND	-	-
TX13094	Primark	Germany	unknown	t-shirt	100% cotton	1.2	<5	110 000	<0.1	-	-	-	-
TX13095	Primark	Spain	unknown	shorts	100% cotton	48	-	-	-	-	-	-	-
TX13096	Primark	UK	unknown	sweatpants	100% polyster	58	<5	-	-	-	-	77	77
TX13097	Puma	China	Indonesia	shoes	leather and other materials; lining textile and other materials	7.3	<5	-	<0.1 - 401	25.2	ND	-	-
TX13098	Puma	Germany	Turkey	football shirt	100% polyester	25	-	-	<0.1	-	-	126	126
TX13099	Puma	Greece	Bangladesh	t-shirt	65% polyester, 35% cotton	5.5	-	-	-	-	-	95	147
TX13100	Puma	Indonesia	China	shoes	Upper leather and other materials; lining textile; sole rubber	340	<5	-	0.44 - 105	-	-	-	-
TX13101	Puma	Italy	Bangladesh	t-shirt	100% cotton	<1.0	<5	-	-	-	-	-	-
TX13102	Puma	Turkey	Bangladesh	t-shirt	65% polyester, 35% cotton	17	<5	120	<0.1 - 0.48	-	-	100	154
TX13106	Uniqlo	Japan	China	polo shirt	100% polyester	<1.0	-	-	<0.1	-	-	86	86
TX13107	Uniqlo	Japan	China	t-shirt	65% polyster, 35% cotton	26	-	96	<0.1	-	-	141	217
TX13108	Uniqlo	Philippines	Vietnam	Jacket	100% polyester	<1.0	<5	-	-	ND	2346	73	73

Table A1. Details of all articles, including the concentrations of NPEs, carcinogenic amines, phthalates, organotins, PFCs and antimony. For carcinogenic amines '<5 mg/kg' indicates that all quantified amines were below the detection limit (<5 mg/kg); For phthalates, organotins and PFCs, the total concentration of the quantified individual compounds in each group is given, with data for individual phthalates, organotins and PFCs provided in Appendices 2, 3 and 4 respectively; For organotins, a range of values is given for some articles where more than one type of fabric was analysed; ND – not detected; '-' indicates not tested. * Where fabric was composed of mixed fibres, the concentration of antimony in polyester was calculated from fabric composition information, on the basis that all antimony arose from the polyester fibre within the fabric blend

Appendix 2. Concentrations of individual phthalates in the 35 articles tested

Sample code	Brand	Type of product	DiBP (mg/kg)	DMP (mg/kg)	DEP (mg/kg)	DnBP (mg/kg)	BBP (mg/kg)	DEHP (mg/kg)	DnOP (mg/kg)	DINP (mg/kg)	DIDP (mg/kg)	Total* (mg/kg)
TX13002	Adidas	t-shirt	**44**	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	**44**
TX13005	Adidas	football shirt	**12**	<3.0	**21**	**18**	<3.0	**11**	<3.0	<3.0	<3.0	**50**
TX13006	Adidas	Swimwear	<3.0	<3.0	**12**	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	**12**
TX13007	Adidas	t-shirt	**25**	<3.0	**22**	**19**	<3.0	**13**	<3.0	<3.0	<3.0	**54**
TX13009	Adidas	t-shirt	<3.0	<3.0	<3.0	**3.8**	<3.0	**17**	<3.0	<3.0	<3.0	**21**
TX13010	Adidas	t-shirt	**15**	<3.0	**5.0**	**6.5**	<3.0	**13**	<3.0	**5.9**	<3.0	**45**
TX13015	American Apparel	baby one-piece	<3.0	<3.0	<3.0	<3.0	<3.0	**3.9**	<3.0	**5900**	**190**	**6100**
TX13017	Burberry	t-shirt	**4.5**	<3.0	<3.0	**6.0**	<3.0	<3.0	<3.0	<3.0	<3.0	**11**
TX13028	C&A	baby onesie	**3.8**	<3.0	<3.0	**4.6**	<3.0	**6.5**	<3.0	<3.0	<3.0	**15**
TX13029	C&A	t-shirt	<3.0	<3.0	**11**	<3.0	<3.0	**3.9**	<3.0	<3.0	<3.0	**15**
TX13031	C&A	t-shirt	**5.8**	<3.0	<3.0	**120**	<3.0	**4.2**	<3.0	<3.0	<3.0	**130**
TX13032	C&A	baby t-shirt	<3.0	<3.0	<3.0	**66**	<3.0	**6.4**	<3.0	<3.0	<3.0	**72**
TX13040	Disney	Dress	<3.0	<3.0	<3.0	**5.6**	<3.0	**58**	<3.0	<3.0	<3.0	**63**
TX13043	Disney	t-shirt	<3.0	<3.0	<3.0	**6.0**	<3.0	<3.0	<3.0	<3.0	<3.0	**6.0**
TX13044	Disney	t-shirt	**4.7**	<3.0	<3.0	**19**	<3.0	**3.1**	<3.0	<3.0	<3.0	**27**
TX13048	GAP	t-shirt	**5.2**	<3.0	**4.1**	**4.3**	<3.0	<3.0	<3.0	<3.0	<3.0	**14**
TX13050	GAP	t-shirt	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
TX13051	GAP	t-shirt	**27**	<3.0	<3.0	**11**	<3.0	**3.7**	<3.0	<3.0	<3.0	**42**
TX13053	GAP	t-shirt	**18**	<3.0	<3.0	<3.0	<3.0	**7.5**	<3.0	<3.0	<3.0	**26**
TX13055	GAP	t-shirt	<3.0	<3.0	<3.0	<3.0	<3.0	**5.5**	<3.0	<3.0	<3.0	**5.5**
TX13056	GAP	t-shirt	<3.0	<3.0	<3.0	<3.0	<3.0	**5.6**	<3.0	<3.0	<3.0	**5.6**
TX13057	GAP	t-shirt	<3.0	<3.0	<3.0	<3.0	<10	<10	<10	<10	<10	<10
TX13063	H&M	t-shirt	<3.0	<3.0	<3.0	**7.6**	<3.0	<3.0	<3.0	<3.0	<3.0	**7.6**
TX13064	H&M	Dress	<3.0	<3.0	<3.0	**45**	<3.0	<3.0	<3.0	<3.0	<3.0	**45**
TX13066	H&M	t-shirt	**10**	<3.0	<3.0	**8.9**	<3.0	<3.0	<3.0	<3.0	<3.0	**19**
TX13069	H&M	Sweater	**6.9**	<3.0	<3.0	**11**	<3.0	**9.3**	<3.0	<3.0	<3.0	**27**
TX13073	Li-Ning	sports top & shorts	**3.3**	<3.0	**4.0**	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	**7.3**
TX13074	Li-Ning	t-shirt	<3.0	<3.0	**9.5**	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	**9.5**
TX13083	Nike	t-shirt	**3.4**	<3.0	**3.2**	**7.9**	<3.0	<3.0	<3.0	<3.0	<3.0	**15**
TX13084	Nike	t-shirt	**6.5**	<3.0	**7.5**	**17**	<3.0	<3.0	<3.0	<3.0	<3.0	**31**
TX13088	Nike	t-shirt	**11**	<3.0	**49**	<3.0	<3.0	**4.7**	<3.0	<3.0	<3.0	**65**
TX13092	Primark	Sweatshirt	**5.0**	<3.0	<3.0	**6.0**	<3.0	<3.0	<3.0	<3.0	<3.0	**11**
TX13094	Primark	t-shirt	<3.0	<3.0	**25**	**19**	**58**	**110 000**	<3.0	**92**	<3.0	**110 000**
TX13102	Puma	t-shirt	**4.5**	<3.0	**23**	**59**	<3.0	**38**	<3.0	<3.0	<3.0	**120**
TX13107	Uniqlo	t-shirt	**14**	<3.0	**3.4**	**71**	<3.0	**8.0**	<3.0	<3.0	<3.0	**96**

Table A2. Concentrations (mg/kg), in plastisol printed fabric, of the following phthalates; dimethyl phthalate (DMP), diethyl phthalate (DEP), di-n-butyl phthalate (DnBP), di-iso-butyl phthalate (DIBP), butylbenzyl phthalate (BBP), di-(2-ethylhexyl) phthalate (DEHP), di-n-octyl phthalate (DNOP), di-iso-nonyl phthalate (DINP) and di-iso-decyl phthalate (DIDP). * Total concentration to 2 significant figures

Appendix 3. Concentrations of individual organotins in the 32 articles tested

Sample Code	Brand	Type of product	material analysed	MBT (mg/kg)	DBT (mg/kg)	DOT (mg/kg)	TBT (mg/kg)	TPhT (mg/kg)	MOT (mg/kg)	TTBT (mg/kg)	TCHT (mg/kg)	Total (mg/kg)
plastisol print												
TX13002a	Adidas	t-shirt	fabric / blue print	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13002b	Adidas		print turquoise+green	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13002c	Adidas		print orange+white+red	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13009a	Adidas	t-shirt	print dark blue	**0.22**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	**0.22**
TX13009b	Adidas		print light blue	**0.32**	**0.16**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	**0.48**
TX13009c	Adidas		print beige	**0.22**	**0.14**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	**0.36**
TX13029	C&A	t-shirt	print green+black+white	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13040a	Disney	dress	fabric / print plastic black+white	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13040b	Disney		print plastic blue+yellow	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13040c	Disney		application plastic blue+yellow	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13043	Disney	t-shirt	fabric / grey print	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13044a	Disney	t-shirt	fabric / print plastic orange	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13044b	Disney		print plastic grey-blue+grey	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13048a	GAP	t-shirt	fabric / print red	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13048b	GAP		print yellow	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13050	GAP	t-shirt	fabric / print plastic beige-brown+ black-brown	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13051a	GAP	t-shirt	fabric / print plastic red	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13051b	GAP		print plastic white+yellow-orange	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13053	GAP	t-shirt	fabric / print blue+multicolour	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13055a	GAP	t-shirt	fabric / print plastic blue	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13055b	GAP		print plastic white+pink	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13056a	GAP	t-shirt	fabric / print plastic orange	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13056b	GAP		print plastic blue+turquoise	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13057a	GAP	t-shirt	fabric / print plastic green+purple	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13057b	GAP		print plastic	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

			pink+rose									
TX13063a	H&M	t-shirt	fabric dark blue	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13063b	H&M		print plastic yellow	**0.32**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	**0.32**
TX13063c	H&M		print plastic red	**0.16**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	**0.16**
TX13069	H&M	sweater	fabric / print plastic green	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13083	Nike	t-shirt	fabric / print plastic grey	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13084	Nike	t-shirt	fabric / print yellow	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13092a	Primark	sweatshirt	fabric / print green	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13092b	Primark		print orange+white	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13092c	Primark		print yellow+red+light blue	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13094a	Primark	t-shirt	fabric / print gold+red	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13094b	Primark		print pink+grey	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13102a	Puma	t-shirt	print white+black	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13102b	Puma		print orange	**0.48**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	**0.48**
TX13107	Uniqlo	t-shirt	fabric / print plastic black+grey	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Footwear												
TX13004a	Adidas	shoes	shell material, pink	<0.1	<0.1	**0.3**	<0.1	<0.1	**0.26**	<0.1	<0.1	**0.56**
TX13004b	Adidas		leather, purple	<0.1	<0.1	**0.28**	<0.1	<0.1	<0.1	<0.1	<0.1	**0.28**
TX13004c	Adidas		leather, white	<0.1	<0.1	**100**	<0.1	<0.1	**6.0**	<0.1	<0.1	**106**
TX13030	C&A	shoes	leather blue+leather light grey	<0.1	<0.1	**<0.1**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13085a	Nike	shoes	insole fibre+foam, lining fibre+foam	<0.1	<0.1	**<0.1**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13085b	Nike		grey foam + fibre	<0.1	<0.1	**<0.1**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13097a	Puma	shoes	insole fabric red+black	<0.1	<0.1	**<0.1**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13097b	Puma		leather red	<0.1	<0.1	**369**	<0.1	<0.1	**32**	<0.1	<0.1	**401**
TX13097c	Puma		synthetic material red	<0.1	<0.1	**2.1**	<0.1	<0.1	**0.42**	<0.1	<0.1	**2.52**
TX13097d	Puma		fabric lining red flap	<0.1	<0.1	**<0.1**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13097e	Puma		synthetic material red/white	<0.1	<0.1	**0.56**	<0.1	<0.1	**0.43**	<0.1	<0.1	**0.99**
TX13100a	Puma	shoes	foam green	<0.1	<0.1	**1.7**	<0.1	<0.1	**0.4**	<0.1	<0.1	**2.1**
TX13100b	Puma		upper leather black	<0.1	<0.1	**71**	<0.1	<0.1	**34**	<0.1	<0.1	**105**
TX13100c	Puma		upper synthetic black	<0.1	<0.1	**1.4**	<0.1	<0.1	**11.3**	<0.1	<0.1	**12.7**
TX13100d	Puma		lining fabric black	<0.1	<0.1	**0.18**	<0.1	<0.1	**0.26**	<0.1	<0.1	**0.44**
Sportwear												
TX13005	Adidas	football	fibre, dark blue	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

		shirt										
TX13072a	Li Ning	sports shirt	fabric	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13072b	Li Ning		print plastic pink/grey	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13073	Li Ning	sports top & shorts	fabric white+blue+dark blue	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13087	Nike	running top	grey fibre+mesh	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13098	Puma	football shirt	fabric yellow+black	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TX13106	Uniqlo	polo shirt	fabric blue	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Table A3. Concentrations (mg/kg) of the following organotins; monobutyl tin (MBT), dibutyl tin (DBT), dioctyltin (DOT), Tributyltin (TBT), Triphenyltin (TPhT), Monooctyltin (MOT), Tetrabutyltin (TTBT), Tricyclohexyltin (TCHT)

Appendix 4. Concentrations of individual PFCs in the 15 articles tested

Sample Code	Brand	Type of product		Total (µg/kg)	PFBS (ng/kg)	PFHxS (ng/kg)	PFHpS (ng/kg)	PFOS (ng/kg)	PFDS (ng/kg)	PFBA (ng/kg)	PFPA (ng/kg)	PFHxA (ng/kg)	PFHpA (ng/kg)	PFOA (ng/kg)	PFNA (ng/kg)	PFDA (ng/kg)
TX13003a	Adidas	coat	WC	**2.18**	< 1650	< 1650	< 1650	< 1100	< 1650	**2180**	< 1100	< 1100	< 1100	< 1100	< 1100	< 1100
TX13003b	Adidas	coat	WC	**10.2**	< 1040	< 1040	< 1040	< 691	< 1040	< 691	< 691	**814**	< 691	**6530**	**919**	**1900**
TX13026	C&A	jacket	WC	**7.40**	< 727	< 727	< 727	< 485	< 727	**1810**	< 502	**4990**	< 485	**599**	< 485	< 485
TX13065a	H&M	coat	WC	**32.7**	< 706	**20 000**	< 706	< 471	< 706	**3390**	**1240**	**8130**	< 471	< 471	< 471	< 471
TX13065b	H&M	coat	WC	**314**	**896**	**300000**	**5340**	**4460**	< 762	**1470**	**1140**	**583**	< 508	< 508	< 508	< 508
TX13067a	H&M	trousers	WC	**2290**	**8750**	**2 260 000**	< 7590	< 5060	< 7590	**12 800**	< 5060	**6790**	< 5060	< 5060	< 5060	< 5060
TX13067b	H&M	trousers	WC	**26.4**	< 7460	**21300**	< 7460	< 4970	< 7460	< 4970	< 4970	**5130**	< 4970	< 4970	< 4970	< 4970
TX13082	Nike	coat	WC	**29.7**	< 2060	< 2060	< 2060	< 1370	< 2060	**10 600**	< 1370	< 1370	< 1370	**7400**	< 1370	**5950**
TX13093	Primark	coat	WC	**2.43**	< 2170	**2430**	< 2170	< 1450	< 2170	< 1450	< 1450	< 1450	< 1450	< 1450	< 1450	< 1450
TX13108	Uniqlo	jacket	WC	ND	< 2060	< 2060	< 2060	< 1370	< 2060	< 1370	< 1370	< 1370	< 1370	< 1370	< 1370	< 1370
TX13004a	Adidas	shoes	F	**2.55**	< 1350	< 1350	< 1350	**978**	< 1350	**1580**	< 900	< 900	< 900	< 900	< 900	< 900
TX13004b	Adidas	shoes	F	ND	< 724	< 724	< 724	< 483	< 724	< 1090	< 483	< 483	< 483	< 483	< 483	< 483
TX13085	Nike	shoes	F	**2.83**	**769**	< 722	< 722	< 481	< 722	**2060**	< 481	< 481	< 481	< 481	< 481	< 481
TX13097	Puma	shoes	F	**25.2**	**25 200**	< 1540	< 1540	< 1030	< 1540	< 1030	< 1030	< 1030	< 1030	< 1030	< 1030	< 1030
TX13006a	Adidas	swimwear	S	**68.0**	< 1050	< 1050	< 1050	< 702	< 1050	**2200**	< 702	< 702	< 702	**65800**	< 702	< 702
TX13006b	Adidas	swimwear	S	**68.0**	< 613	< 613	< 613	< 409	< 613	< 409	< 409	< 409	< 409	**68000**	< 409	< 409
TX13016	Burberry	swimwear	S	**1.39**	< 792	< 792	< 792	< 528	< 792	**1390**	< 528	< 528	< 528	< 528	< 528	< 528
TX13023	Burberry	swimwear	S	**2.76**	< 687	< 687	< 687	**2110**	< 687	**655**	< 458	< 458	< 458	< 458	< 458	< 458
TX13042	Disney	swimwear	S	**4.26**	< 1110	< 1110	< 1110	< 737	< 1110	**2500**	< 737	< 737	< 737	**1760**	< 737	< 737
TX13091	Primark	swimwear	S	**2.01**	< 1400	< 1400	< 1400	< 931	< 1400	**2010**	< 931	< 931	< 931	< 931	< 931	< 931

Table A4a. Concentrations of ionic PFCs* by mass (ng/kg; 1000 ng/kg = 1 µg/kg) in waterproof clothing (WC), footwear (F) or swimwear (S), with total concentration for 21 compounds (µg/kg)

Sample Code	Brand	Type of product		PFUnA (ng/kg)	PFDoA (ng/kg)	PFTrA (ng/kg)	PFTeA (ng/kg)	PFOSA (ng/kg)	PF-3,7 DMOA (ng/kg)	HPFHpA (ng/kg)	H2PFDA (ng/kg)	H4PFOS; 6:2 FTS (ng/kg)
TX13003a	Adidas	coat	WC	< 1100	< 1100	< 1100	< 1100	< 1100	< 2190	< 2190	< 2190	< 1650
TX13003b	Adidas	coat	WC	< 691	< 691	< 691	< 691	< 691	< 1380	< 1380	< 1380	< 1040
TX13026	C&A	jacket	WC	< 485	< 485	< 485	< 485	< 485	< 969	< 969	< 969	< 727
TX13065a	H&M	coat	WC	< 471	< 471	< 471	< 471	< 471	< 941	< 941	< 941	< 706
TX13065b	H&M	coat	WC	< 508	< 508	< 508	< 508	< 508	< 1020	< 1020	< 1020	< 762
TX13067a	H&M	trousers	WC	< 5060	< 5060	< 5060	< 5060	< 5060	< 10 100	< 10 100	< 10 100	< 7590
TX13067b	H&M	trousers	WC	< 4970	< 4970	< 4970	< 4970	< 4970	< 9940	< 9940	< 9940	< 7460
TX13082	Nike	coat	WC	< 1370	**5770**	< 1370	< 1370	< 1370	< 2740	< 2740	< 2740	< 2060
TX13093	Primark	coat	WC	< 1450	< 1450	< 1450	< 1450	< 1450	< 2900	< 2900	< 2900	< 2170
TX13108	Uniqlo	jacket	WC	< 1370	< 1370	< 1370	< 1370	< 1370	< 2750	< 2750	< 2750	< 2060
TX13004a	Adidas	shoes	F	< 900	< 900	< 900	< 900	< 900	< 1800	< 1800	< 1800	< 1350
TX13004b	Adidas	shoes	F	< 483	< 483	< 483	< 483	< 483	< 965	< 965	< 965	< 724
TX13085	Nike	shoes	F	< 481	< 481	< 481	< 481	< 481	< 962	< 962	< 962	< 722
TX13097	Puma	shoes	F	< 1030	< 1030	< 1030	< 1030	< 1030	< 2050	< 2050	< 2050	< 1540
TX13006a	Adidas	swimwear	S	< 702	< 702	< 702	< 702	< 702	< 1400	< 1400	< 1400	< 1050
TX13006b	Adidas	swimwear	S	< 409	< 409	< 409	< 409	< 409	< 818	< 818	< 818	< 613
TX13016	Burberry	swimwear	S	< 528	< 528	< 528	< 528	< 528	< 1060	< 1060	< 1060	< 792
TX13023	Burberry	swimwear	S	< 458	< 458	< 458	< 458	< 458	< 916	< 916	< 916	< 687
TX13042	Disney	swimwear	S	< 737	< 737	< 737	< 737	< 737	< 1470	< 1470	< 1470	< 1110
TX13091	Primark	swimwear	S	< 931	< 931	< 931	< 931	< 931	< 1860	< 1860	< 1860	< 1400

Table A4a. continued; concentrations of ionic PFCs* by mass (ng/kg; 1000 ng/kg = 1 μg/kg) in waterproof clothing (WC), footwear (F) or swimwear (S)

Sample Code	Brand	Type of product		Total (µg/m²)	PFBS (µg/m²)	PFHxS (µg/m²)	PFHpS (µg/m²)	PFOS (µg/m²)	PFDS (µg/m²)	PFBA (µg/m²)	PFPA (µg/m²)	PFHxA (µg/m²)	PFHpA (µg/m²)	PFOA (µg/m²)	PFNA (µg/m²)	PFDA (µg/m²)
TX13003a	Adidas	coat	WC	**0.159**	<0,120	<0,120	<0,120	<0,080	<0,120	**0.159**	<0,080	<0,080	<0,080	<0,080	<0,080	<0,080
TX13003b	Adidas	coat	WC	**0.729**	<0,074	<0,074	<0,074	<0,049	<0,074	<0,049	<0,049	**0.058**	<0,049	**0.466**	**0.066**	**0.136**
TX13026	C&A	jacket	WC	**2.52**	<0,247	<0,247	<0,247	<0,164	<0,247	**0.615**	<0,170	**1.70**	<0,164	**0.204**	<0,164	<0,164
TX13065a	H&M	coat	WC	**6.87**	<0,148	**4.20**	<0,148	<0,098	<0,148	**0.712**	**0.260**	**1.71**	<0,098	<0,098	<0,098	<0,098
TX13065b	H&M	coat	WC	**67.2**	**0.192**	**64.2**	**1.142**	**0.954**	<0,162	**0.314**	**0.244**	**0.125**	<0,108	<0,108	<0,108	<0,108
TX13067a	H&M	trousers	WC	**549**	**2.10**	**542**	<1,821	<1,214	<1,821	**3.072**	<1,214	**1.63**	<1,214	<1,214	<1,214	<1,214
TX13067b	H&M	trousers	WC	**5.22**	<1,475	**4.21**	<1,475	<0,982	<1,475	<0,982	<0,982	**1.02**	<0,982	<0,982	<0,982	<0,982
TX13082	Nike	coat	WC	**2.08**	<0,144	<0,144	<0,144	<0,095	<0,144	**0.742**	<0,095	<0,095	<0,095	**0.518**	<0,095	**0.417**
TX13093	Primark	coat	WC	**0.170**	<0,151	**0.170**	<0,151	<0,101	<0,151	<0,101	<0,101	<0,101	<0,101	<0,101	<0,101	<0,101
TX13108	Uniqlo	jacket	WC	ND	<0,144	<0,144	<0,144	<0,095	<0,144	<0,095	<0,095	<0,095	<0,095	<0,095	<0,095	<0,095
TX13004a	Adidas	shoes	F	**2.23**	<1,180	<1,180	<1,180	**0.855**	<1,180	**1.38**	<0,787	<0,787	<0,787	<0,787	<0,787	<0,787
TX13004b	Adidas	shoes	F	ND	<1,105	<1,105	<1,105	<0,737	<1,105	<1,664	<0,737	<0,737	<0,737	<0,737	<0,737	<0,737
TX13085	Nike	shoes	F	**2.29**	**0.623**	<0,584	<0,584	<0,389	<0,584	**1.67**	<0,389	<0,389	<0,389	<0,389	<0,389	<0,389
TX13097	Puma	shoes	F	**19.7**	**19.7**	<1,203	<1,203	<0,804	<1,203	<0,804	<0,804	<0,804	<0,804	<0,804	<0,804	<0,804
TX13006a	Adidas	swimwear	S	**15.8**	<0,244	<0,244	<0,244	<0,163	<0,244	**0.513**	<0,163	<0,163	<0,163	**15.3**	<0,163	<0,163
TX13006b	Adidas	swimwear	S	**14.5**	<0,130	<0,130	<0,130	<0,087	<0,130	<0,087	<0,087	<0,087	<0,087	**14.5**	<0,087	<0,087
TX13016	Burberry	swimwear	S	**0.264**	<0,150	<0,150	<0,150	<0,100	<0,150	**0.264**	<0,100	<0,100	<0,100	<0,100	<0,100	<0,100
TX13023	Burberry	swimwear	S	**0.607**	<0,151	<0,151	<0,151	**0.464**	<0,151	**0.144**	<0,100	<0,100	<0,100	<0,100	<0,100	<0,100
TX13042	Disney	swimwear	S	**0.596**	<0,155	<0,155	<0,155	<0,103	<0,155	**0.350**	<0,103	<0,103	<0,103	**0.246**	<0,103	<0,103
TX13091	Primark	swimwear	S	**0.439**	<0,305	<0,305	<0,305	<0,203	<0,305	**0.439**	<0,203	<0,203	<0,203	<0,203	<0,203	<0,203

Table A4b. Concentrations of ionic PFCs* by area (µg/m²) in waterproof clothing (WC), footwear (F) or swimwear (S), with total concentration for 21 compounds (µg/m²)

sample Code	Brand	Type of product		PFUnA (µg/m²)	PFDoA (µg/m²)	PFTrA (µg/m²)	PFTeA (µg/m²)	PFOSA (µg/m²)	PF-3,7-DMOA (µg/m²)	HPFHpA (µg/m²)	H2PFDA (µg/m²)	H4PFOS; 6:2 FTS (µg/m²)
TX13003a	Adidas	coat	WC	<0,080	<0,080	<0,080	<0,080	<0,080	<0,159	<0,159	<0,159	<0,120
TX13003b	Adidas	coat	WC	<0,049	<0,049	<0,049	<0,049	<0,049	<0,098	<0,098	<0,098	<0,074
TX13026	C&A	jacket	WC	<0,164	<0,164	<0,164	<0,164	<0,164	<0,329	<0,329	<0,329	<0,247
TX13065a	H&M	coat	WC	<0,098	<0,098	<0,098	<0,098	<0,098	<0,197	<0,197	<0,197	<0,148
TX13065b	H&M	coat	WC	<0,108	<0,108	<0,108	<0,108	<0,108	<0,218	<0,218	<0,218	<0,162
TX13067a	H&M	trousers	WC	<1,214	<1,214	<1,214	<1,214	<1,214	<2,424	<2,424	<2,424	<1,821
TX13067b	H&M	trousers	WC	<0,982	<0,982	<0,982	<0,982	<0,982	<1,965	<1,965	<1,965	<1,475
TX13082	Nike	coat	WC	<0,095	0.404	<0,095	<0,095	<0,095	<0,191	<0,191	<0,191	<0,144
TX13093	Primark	coat	WC	<0,101	<0,101	<0,101	<0,101	<0,101	<0,203	<0,203	<0,203	<0,151
TX13108	Uniqlo	jacket	WC	<0,095	<0,095	<0,095	<0,095	<0,095	<0,192	<0,192	<0,192	<0,144
TX13004a	Adidas	shoes	F	<0,787	<0,787	<0,787	<0,787	<0,787	<1,574	<1,574	<1,574	<1,180
TX13004b	Adidas	shoes	F	<0,737	<0,737	<0,737	<0,737	<0,737	<1,473	<1,473	<1,473	<1,105
TX13085	Nike	shoes	F	<0,389	<0,389	<0,389	<0,389	<0,389	<0,778	<0,778	<0,778	<0,584
TX13097	Puma	shoes	F	<0,804	<0,804	<0,804	<0,804	<0,804	<1,601	<1,601	<1,601	<1,203
TX13006a	Adidas	swimwear	S	<0,163	<0,163	<0,163	<0,163	<0,163	<0,326	<0,326	<0,326	<0,244
TX13006b	Adidas	swimwear	S	<0,087	<0,087	<0,087	<0,087	<0,087	<0,174	<0,174	<0,174	<0,130
TX13016	Burberry	swimwear	S	<0,100	<0,100	<0,100	<0,100	<0,100	<0,201	<0,201	<0,201	<0,150
TX13023	Burberry	swimwear	S	<0,100	<0,100	<0,100	<0,100	<0,100	<0,201	<0,201	<0,201	<0,151
TX13042	Disney	swimwear	S	<0,103	<0,103	<0,103	<0,103	<0,103	<0,205	<0,205	<0,205	<0,155
TX13091	Primark	swimwear	S	<0,203	<0,203	<0,203	<0,203	<0,203	<0,405	<0,405	<0,405	<0,305

Table A4b. Continued; concentrations of ionic PFCs* by area (µg/m²) in waterproof clothing (WC), footwear (F) or swimwear (S)

sample Code	Brand	Type of product		Total (µg/kg)	6:2 FTA (µg/kg)	8:2 FTA (µg/kg)	10:2 FTA (µg/kg)	4:2 FTOH (µg/kg)	6:2 FTOH (µg/kg)	8:2 FTOH (µg/kg)	10:2 FTOH (µg/kg)	MeFOSE (µg/kg)	EtFOSE (µg/kg)	MeFOSA (µg/kg)	EtFOSA (µg/kg)
TX13003	Adidas	coat	WC	**2420**	< 14	**240**	**30**	< 47	< 160	**1700**	**450**	< 9	< 9	< 9	< 9
TX13026	C&A	jacket	WC	**380**	< 14	< 14	< 14	< 48	**380**	< 130	< 58	< 10	< 10	< 10	< 10
TX13065	H&M	coat	WC	ND	< 15	< 15	< 15	< 49	< 170	< 130	< 59	< 10	< 10	< 10	< 10
TX13067	H&M	trousers	WC	ND	< 14	< 14	< 14	< 47	< 160	< 120	< 56	< 9	< 9	< 9	< 9
TX13082	Nike	coat	WC	**6970**	< 14	**380**	**87**	< 46	< 160	**5100**	**1400**	< 9	< 9	< 9	< 9
TX13093	Primark	coat	WC	ND	< 14	< 14	< 14	< 48	< 160	< 130	< 58	< 10	< 10	< 10	< 10
TX13108	Uniqlo	jacket	WC	**2350**	< 15	**120**	**26**	< 50	< 170	**1700**	**500**	< 10	< 10	< 10	< 10
TX13004	Adidas	shoes	F	**499**	< 15	**19**	< 15	< 49	< 170	**370**	**110**	< 10	< 10	< 10	< 10
TX13085	Nike	shoes	F	ND	< 12	< 12	< 12	< 40	< 140	< 100	< 48	< 8	< 8	< 8	< 8
TX13097	Puma	shoes	F	ND	< 13	< 13	< 13	< 42	< 140	< 110	< 50	< 8	< 8	< 8	< 8
TX13006	Adidas	swimwear	S	ND	< 15	< 15	< 15	< 49	< 170	< 130	< 59	< 10	< 10	< 10	< 10
TX13016	Burberry	swimwear	S	ND	< 14	< 14	< 14	< 48	< 160	< 130	< 58	< 10	< 10	< 10	< 10
TX13023	Burberry	swimwear	S	ND	< 14	< 14	< 14	< 47	< 160	< 120	< 57	< 10	< 10	< 10	< 10
TX13042	Disney	swimwear	S	ND	< 14	< 14	< 14	< 46	< 160	< 120	< 56	< 9	< 9	< 9	< 9
TX13091	Primark	swimwear	S	ND	< 14	< 14	< 14	< 48	< 160	< 120	< 57	< 10	< 10	< 10	< 10

Table A4c. Concentrations of volatile PFCs* by mass (µg/kg; 1000 ng/kg = 1 µg/kg) in waterproof clothing (WC), footwear (F) or swimwear (S)

Sample Code	Brand	Type of product		Total (μg/m^2)	6:2 FTA (μg/m^2)	8:2 FTA (μg/m^2)	10:2 FTA (μg/m^2)	4:2 FTOH (μg/m^2)	6:2 FTOH (μg/m^2)	8:2 FTOH (μg/m^2)	10:2 FTOH (μg/m^2)	MeFOSE (μg/m^2)	EtFOSE (μg/m^2)	MeFOSA (μg/m^2)	EtFOSA (μg/m^2)
TX13003	Adidas	coat	WC	**181**	<1,04	**18.0**	**2.24**	<3,51	<11,9	**127**	**33.7**	<0,67	<0,67	<0,67	<0,67
TX13026	C&A	jacket	WC	**125**	<4,62	<4,62	<4,62	<15,8	**125**	<42,9	<19,1	<3,3	<3,3	<3,3	<3,3
TX13065	H&M	coat	WC	ND	<3,15	<3,15	<3,15	<10,2	<35,7	<27,3	<12,3	<2,1	<2,1	<2,1	<2,1
TX13067	H&M	trousers	WC	ND	<3,5	<3,5	<3,5	<11,7	<40	<30	<14	<2,25	<2,25	<2,25	<2,25
TX13082	Nike	coat	WC	**557**	<1,12	**30.4**	**6.96**	<3,68	<12,8	**408**	**112**	<0,72	<0,72	<0,72	<0,72
TX13093	Primark	coat	WC	ND	<0,97	<0,97	<0,97	<3,35	<11,1	<9,09	<4,05	<0,69	<0,69	<0,69	<0,69
TX13108	Uniqlo	jacket	WC	**164**	<1,05	**8.40**	**1.82**	<3,50	<11,9	**119**	**35.0**	<0,70	<0,70	<0,70	<0,70
TX13004	Adidas	shoes	F	**390**	<11,7	**14.8**	<11,7	<38,2	<132,	**289**	**85.9**	<7,81	<7,81	<7,81	<7,81
TX13085	Nike	shoes	F	ND	<10	<10	<10	<33,3	<116,	<83,3	<40	<6,66	<6,66	<6,66	<6,66
TX13097	Puma	shoes	F	ND	<9,23	<9,23	<9,23	<29,8	<99,4	<78,1	<35,5	<5,68	<5,68	<5,68	<5,68
TX13006	Adidas	swimwear	S	ND	<3,32	<3,32	<3,32	<10,8	<37,6	<28,7	<13,0	<2,21	<2,21	<2,21	<2,21
TX13016	Burberry	swimwear	S	ND	<2,66	<2,66	<2,66	<9,12	<30,4	<24,7	<11,0	<1,9	<1,9	<1,9	<1,9
TX13023	Burberry	swimwear	S	ND	<3,08	<3,08	<3,08	<10,3	<35,2	<26,4	<12,5	<2,2	<2,2	<2,2	<2,2
TX13042	Disney	swimwear	S	ND	<1,92	<1,92	<1,92	<6,33	<22,0	<16,5	<7,71	<1,23	<1,23	<1,23	<1,23
TX13091	Primark	swimwear	S	ND	<3,12	<3,12	<3,12	<10,7	<35,7	<26,7	<12,7	<2,23	<2,23	<2,23	<2,23

Table A4d. Concentrations of volatile PFCs* by area (μg/m^2) in waterproof clothing (WC), footwear (F) or swimwear (S)

* Individual PFCs included the following;
Ionic PFCs; Perfluorobutane sulfonate (PFBS), perfluorohexane sulfonate (PFHxS), perfluoroheptane sulfonate (PFHpS), perfluorooctane sulfonate (PFOS), perfluorodecane sulfonate (PFDS), perfluorobutanoate (PFBA), perfluoropentanoate (PFPA), perfluorohexanoate (PFHxA), perfluoroheptanoate (PFHpA), perfluorooctanoate (PFOA), perfluorononanoate (PFNA), perfluorodecanoate (PFDA), perfluoroundecanoate (PFUnA), perfluorododecanoate (PFDoA), perfluorotridecanoate (PFTrA), perfluorotetradecanoate (PFTeA), perfluorooctane sulfonamide (PFOSA), perfluoro-3,7-dimethyloctanoate (PF-3,7-DMOA), 7H-dodecafluoroheptanoate (HPFHpA), 2H,2H-Perfluorodecanoate (H2PFDA), 2H,2H,3H,3H-Perfluoroundecanoate (H4PFUnA)
Volatile PFCs; 1H,1H,2H,2H-Perfluoroctylacrylate (6:2 FTA), 1H,1H,2H,2H-Perfluorodecylacrylate (8:2 FTA), 1H,1H,2H,2H-Perfluorododecylacrylate (10:2 FTA), 1H,1H,2H,2H-Perfluoro-1-hexanol (4:2 FTOH), 1H,1H,2H,2H-Perfluoro-1-oktanol (6:2 FTOH), 1H,1H,2H,2H-Perfluoro-1-decanol (8:2 FTOH), 1H,1H,2H,2H-Perfluoro-1-dodecanol (10:2 FTOH), 2-(N-methylperfluoro-1-octanesulfonamido)-ethanol (MeFOSE), 2-(N-ethylperfluoro-1-octanesulfonamido)-ethanol (EtFOSE), N-methylperfluoro-1-octansulfonamide (MeFOSA), N-ethylperfluoro-1-octanesulfonamide (EtFOSA).