Nonylphenol ethoxylates (NPEs) in textile products, and their release through laundering

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Contents

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Executive Summary

Nonylphenol ethoxylates (NPEs) are a group of chemicals used in the manufacture of textiles, in particular as surfactants and detergents. Where released, either directly into surface waters or via wastewater treatment facilities, NPEs can break down to form nonylphenols, a group of persistent, bioaccumulative and toxic chemicals.

The use of NPEs during the manufacture of textiles can also leave residues of these chemicals within the final products. This study was carried out to improve understanding of the presence and levels of NPEs within textile products manufactured in and purchased from a wide range of countries, and representing a number of major clothing brands.

The concentrations of NPEs were quantified in 78 articles (including sports and recreational clothing and shoes) purchased during April and May 2011 in 18 countries – including 10 within the EU – and representing 13 different countries of manufacture. For the majority of products (71 of 78), a section of plain fabric was analysed, while for the 7 other products a section of fabric bearing a plastisol[1] print was used.

Results demonstrate the widespread presence of NPEs within the textile products tested, across almost all countries of manufacture, countries of purchase and brands 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.

Key findings

- 52 (two-thirds) of the 78 articles tested positive for the presence of NPEs at concentrations above the limit of detection (1 mg/kg).
- Where detected, levels of NPEs in plain fabric samples ranged from just above 1 mg/kg to 1100 mg/kg. Levels in samples bearing a plastisol print ranged from 5.0 mg/kg up to 27000 mg/kg, the latter being the highest concentrations among all samples.
- NPEs were detected in products:
  - from 12 of the 13 countries of manufacture, the exception being one sample from Tunisia;
  - from 14 of the 15 product brands (the exception being two samples from GAP); and
  - purchased in 17 out of the 18 countries (the exception being two samples from Sweden).

A summary of the number of samples containing NPEs within various ranges of concentration is given below

NPE concentration range (mg/kg)	Number of samples (of 78 analysed)
<1	26 samples (33%)
1 – 10	17 samples (22%)
10 – 100	21 samples (27%)
100 – 1000	12 samples (15%)
>1000	2 samples (3%)

Table 1. The number of samples (of the 78 items tested) within various NPE concentration ranges.

Given the wide range of NPE concentrations found among individual samples and the relatively small number of products we were able to analyse for any given category (compared to the vast number of products manufactured and sold per country or per brand), it is not possible to draw more general conclusions on the variability of NPE concentrations between product types, country of purchase or manufacture, product brand or fabric type.

It should be noted that the concentration of NPEs in a product is not indicative of the amount of NPEs used during its manufacture as residue levels will inevitably depend on a range of other factors, including the number and efficacy of wash cycles employed during product finishing. For the same reason, absence of NPE residues from any particular product cannot be taken to confirm absence of use of NPEs at some stage during the manufacturing processes.

The possible presence of residues of other hazardous substances deriving from product manufacture was not investigated in this study.

1 Plastisol is a suspension of PVC in a plasticiser, used as ink for screen-printing images and logos on to textiles

Washing of articles

The effect of washing under simulated standard domestic laundering conditions was also investigated for some of the textile products in which NPEs were identified. This aspect was investigated for 14 samples, consisting of 12 samples of plain fabric (with concentrations in the unwashed fabric ranging from 11 mg/kg to 1100 mg/kg), and 2 samples of fabric bearing a plastisol print (with unwashed fabric concentrations of 470 mg/kg and 27000 mg/kg respectively).

Key findings

- For all samples, the concentration of NPEs in the washed fabric was lower than that in an unwashed portion of identical fabric from the same item following a single wash; washed fabric concentrations of NPEs were between 6% and 83% of the concentrations in the unwashed portions of the plain fabrics, and were 44% and 91% of the unwashed fabric concentrations for the two plastisol-printed samples.
- The results equate to between 17% and 94% of NPE residues being washed out from the plain fabric samples during a single wash, and between 9% and 56% from plastisol-printed samples, assuming that the unwashed and washed portions from each item initially contained the same concentration of NPEs.
- For half the plain fabric samples (6 of 12), concentrations of NPEs in the washed portion were below 20% of those determined in the unwashed portions of the same fabric.
- The apparent reductions in NPE concentrations due to washing were largely independent of the initial concentrations in the unwashed products. In other words, the fabrics yielding the greatest difference between NPE concentrations in washed and unwashed portions were not necessarily those with the highest NPE concentrations in the unwashed portions.
- The type of fabric that a product is made from does not appear to influence the extent to which concentrations are lower in the washed portion compared to the unwashed portion.

These results indicate that a single wash, using conditions intended to simulate standard domestic laundering, can wash out a substantial fraction of NPE residues present within textile products, with more than 80% being washed out for half the plain fabric samples.

As far as we are aware, this is the first study to report differences in the amounts of NPEs in fabric products before and after washing using simulated domestic laundering conditions. Given that NPEs are readily water soluble, it is not surprising that residues are washed out from fabrics to this extent, even after a single wash.

The release of NPEs from the washing of clothes and other fabric products contributes to ongoing inputs of nonylphenol to surface waters, predominantly via urban wastewater and sewage treatment plants. Although the contribution of NPEs from any given article of clothing will be relatively small, the sheer volume of clothing being sold and subsequently washed means that the total quantities being released may be substantial. Within the EU, where the use of nonylphenol and NPEs in clothing manufacture has effectively been banned, releases due to the washing of such products has been estimated to constitute by far the largest source of these chemicals entering waste water treatment facilities in some instances. Despite requirements made in 2000 under the Water Framework Directive (WFD) that all releases of nonylphenol within the EU are phased out within 20 years, inputs to surface waters continue within the EU via this route.

Until restrictions on the import of textile products containing residues of NPEs into the EU are in place, alongside product brands completely eliminating all uses of NPEs in their supply chains, releases of NPEs from textiles and the resulting inputs of nonylphenol to surface waters will continue to contribute to overall releases within the EU.

Similarly, release of these substances will continue in countries outside the EU where few or no effective controls on their manufacture, use and release are currently in place, both from the manufacture of products and their subsequent washing.

Introduction

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. Where released, either directly into surface waters or via wastewater treatment facilities, NPEs can break down to form nonylphenols, a closely-related group of persistent, bioaccumulative and toxic chemicals (OSPAR 2004 Jobling *et al*. 1996). The manufacture, use and release of nonylphenol and NPE are regulated in some regions (OSPAR 1998, EU 2003), though uses continue elsewhere. Additional information on nonylphenol and NPEs, including on their hazardous properties, is available in a previous related report (Greenpeace 2011a).

The use of NPEs during the manufacture of textiles can leave residues of NPEs within the final product. Some previous studies have reported the presence of NPEs within textile products, though these studies have tended to focus on a relatively small number of products sold within a single country (Laursen *et al*. 2003, Greenpeace 2004, LGC 2006, Månsson *et al*. 2008, SSNC 2008).

This study was carried out to provide a more comprehensive and up-to-date understanding of the presence and levels of NPEs within textile products across a wide range of countries of manufacture and sale, and for a wide range of major clothing brands (Part 1). In addition, this study investigated the potential for NPEs (which are water-soluble) to be washed out from products under conditions intended to simulate standard domestic laundering (Part 2).

Part 1 – Quantification of NPEs in textile products

The concentrations of NPEs were quantified in articles of clothing and fabric-based shoes. This study involved the analysis of 78 articles (including sports and recreational clothing and shoes) bearing the logos of 15 leading clothing brands. These products were purchased in 18 countries, including 10 within the EU. According to their labels, the products were manufactured in at least 13 different countries, with three items being of unknown manufacturing origin. The products included those manufactured from natural and from synthetic fabrics, and included items designed for men, women and children. The study covered a variety of items, including shirts, jackets, trousers, underwear and fabric based shoes.

For the majority of products (71 of 78), a section of plain fabric from the item was tested. For the remaining 7 products, the concentration of NPEs was quantified in a section of fabric bearing a plastisol print of an image, logo or text.

The results from this section have also been reported in '*Dirty Laundry 2: Hung Out to Dry'* (Greenpeace 2011b).

Methodology

The 78 products were purchased during April and May 2011 at the flagship stores of the clothing brands, or other stores authorised to sell the branded products, in 18 countries (see Appendix 1 for details). While still in the store, purchased products were immediately sealed in individual 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 an independent accredited laboratory for analysis.

Quantification of nonylphenol ethoxylates

For 71 of the 78 products, a section of fabric that did not bear any printing was removed from the product for subsequent analysis. For the remaining 7 products, a section bearing a plastisol print of an image, logo or text on the surface was removed from the product for analysis.

Following isolation of a section of fabric, 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 4 to 20 ethoxylate groups. The quantitative results presented below are the sum of the concentrations of the individual nonylphenol ethoxylates with 4-20 ethoxylate groups.

Quality assurance and quality control checks were employed, including the analysis of blank samples, the analysis of a number of samples in duplicate, and the analysis of two intra-laboratory textile reference samples with every batch.

Results and discussion

Of the 78 articles analysed, 52 (two-thirds) tested positive for the presence of NPEs at concentrations above the limit of detection (1 mg/kg). Where detected, levels of NPEs in plain fabric samples ranged from just above 1 mg/kg to 1100 mg/kg. Levels in samples bearing a plastisol print ranged from 5.0 mg/kg up to 27 000 mg/kg, the latter being the highest concentrations among all samples.

Just under one fifth (18%) of the samples contained NPEs at concentrations above 100 mg/kg and, of these, two samples had concentrations over 1000 mg/kg (0.1%). The remainder, almost a half (49%) of all samples tested, contained NPEs at concentrations below 100 mg/kg. A summary of the number of samples containing NPEs within various ranges of concentration is given in Table 1.

Products from 12 of the 13 countries of manufacture contained NPEs above the detection limit (the exception being one sample from Tunisia). Furthermore, NPEs were detected in products from 14 of the 15 product brands (the exception being two samples from GAP), and in products purchased in 17 out of the 18 countries (the exception being two samples from Sweden). A summary of the results is presented in Tables 2 to 4, which include a breakdown of the results by country of purchase, by country of manufacture, and by brand, respectively. The results for individual samples are presented in Appendix 1.

Table 1. The number of samples (of the 78 items tested) within various NPE concentration ranges.

NPE concentration range (mg/kg)	Number of samples (of 78 analysed)
<1	26 samples (33%)
1 – 10	17 samples (22%)
10 – 100	21 samples (27%)
100 – 1000	12 samples (15%)
>1000	2 samples (3%)

Samples with higher NPE concentrations (above 100 mg/kg) were distributed across a range of countries of purchase, countries of manufacture and product brands. Given the wide range of NPE concentrations found among individual samples and the relatively small number of products we were able to analyse for any given category (compared to the vast number of products manufactured and sold per country or per brand), it is not possible to draw more general conclusions on the variability of NPE concentrations between product types, country of purchase or manufacture, product brand or fabric type.

Table 2. The number of samples in which NPEs were identified by country of purchase, with the NPE concentration range and the median NPE concentration for each country (* denotes EU member states).

Country of Purchase	Number of samples	Number tested positive	NPE concentration range (mg/kg)	NPE concentration median (mg/kg)
Argentina	4	4	1.2 - 51	16
Austria *	4	2	<1 - 970	6.3
China	10	7	<1 - 530	14
Czech Republic *	4	1	<1 - 1.8	<1
Denmark *	3	2	<1 - 39	35
Finland *	1	1	660	660
Germany *	7	4	<1 - 680	14
Italy *	4	3	<1 - 240	111
Japan	5	3	<1 - 1100	8.7
Netherlands *	5	3	<1 – 21	1.6
Norway	2	2	13 – 14	14
Philippines	4	2	<1 – 27000	3.8
Russia	4	4	4.4 – 810	15
Spain *	4	3	<1 – 41	21
Sweden *	2	0	<1	<1
Switzerland	6	5	<1 – 160	2.2
Thailand	4	4	2.8 – 470	11
UK *	5	2	<1 – 18	<1
Total	78	52	<1 - 27000	6.3

Table 3. The number of samples in which NPEs were identified by country of manufacture, with the NPE concentration range and the median NPE concentration for each country.

Country of manufacture	Number of samples	Number tested positive	NPE concentration range (mg/kg)	NPE concentration median (mg/kg)
Bangladesh	11	8	<1 - 970	13
Cambodia	2	2	1.2 – 18	9.6
China	28	19	<1 – 1100	10
Egypt	1	1	9.1	9.1
Indonesia	3	2	<1 – 35	2.0
Malaysia	2	2	2.8 – 12	7.4
Pakistan	1	1	240	240
Philippines	4	3	<1 – 27000	111
Sri Lanka	1	1	160	160
Thailand	6	5	<1 – 470	11
Tunisia	1	0	<1	<1
Turkey	9	5	<1 – 47	1.6
Vietnam	6	3	<1 - 140	7.3
Unknown	3	0	<1	<1

Table 4. The number of samples in which NPEs were identified by product brand, with the NPE concentration range and the median NPE concentration for each brand.

Brand	Number of samples	Number tested positive	NPE concentration range (mg/kg)	NPE concentration median (mg/kg)
Abercrombie & Fitch	3	3	18 – 1100	39
Adidas	9	4	<1 - 18	<1
Calvin Klein	4	3	<1 - 160	19
Converse	6	5	<1 - 27000	24
G-Star Raw	5	3	<1 – 41	11
GAP	2	0	<1	<1
H&M	6	4	<1 - 21	4.1
Kappa	5	4	<1 - 970	240
Lacoste	4	1	<1 - 3.6	<1
Li Ning	4	4	2.8 – 680	8.5
Nike	10	5	<1 – 810	<1
Puma	9	7	<1 – 210	4.4
Ralph Lauren	4	3	<1 – 220	43
Uniqlo	4	3	<1 – 25	5.5
Youngor	3	3	19 – 530	190

A summary of the NPE concentrations for different types of fabric is given in Table 5. There are some notable differences between the median concentrations for different fabrics and between the upper values of the concentration ranges for different fabrics, though variability within each fabric type was high and no clear pattern emerges. Due to the small number of samples available from most types of fabric, it is not possible to draw any more generic conclusions on the variability of NPE concentrations between different fabric types.

Table 5. The number of samples in which NPEs were identified by fabric type, with the NPE concentration range and the median NPE concentration for each brand.

Fabric	Number of samples	Number tested positive	NPE concentration range (mg/kg)	NPE concentration median (mg/kg)
Cotton	30	16	<1 – 970	1.4
Polyester	10	7	<1 - 240	9.6
Cotton, elastane	5	4	<1 – 1100	11
Cotton, polyester	4	4	1.8 – 810	355
Polyester, elastane	3	2	<1 – 2.8	1.2
Cotton, polyester, elastane	2	2	2.0 – 8.7	5.4
Nylon, elastane	1	1	9.1	9.1
Plastisol print	7	4	<1 – 27000	5.0
Unknown	16	12	1.1 – 680	18

Part 2. Analysis of selected samples following washing

NPEs are readily water-soluble and residues in fabrics are, therefore, susceptible to loss to the water phase during laundering under standard domestic conditions. For this reason, a number of the textile products in which NPEs were identified were selected for subsequent investigation into the effect on residue concentrations of washing the product under conditions intended to simulate standard domestic laundering. Fourteen samples were selected, consisting of 12 samples of plain fabric and 2 samples of fabric bearing a plastisol print. The 12 plain fabric samples were selected to provide a broad range of concentrations in the unwashed fabric (from 11 mg/kg to 1100 mg/kg), as well as providing a range of different kinds of products and fabrics.

Similarly, the two samples bearing a plastisol print were selected to provide one material with a high concentration of NPEs in the unwashed fabric (27000 mg/kg) and another with a lower concentration (470 mg/kg). Both plastisol samples were isolated from T-shirts in which the fabric type was not specified.

Details of the individual products, including the concentrations of NPEs in the unwashed fabric, the kind of product and the type of fabric are summarised in Table 6, along with the concentrations of NPEs determined in the fabrics following a single wash.

Methodology

Each product was washed separately according to the standard method SS-EN 6330 (domestic washing and drying procedures for textile testing), at 40°C using an eco-labelled washing powder for coloured garments. No subsequent tumble-drying was employed.

For those products in which the plain fabric was being investigated, any printed sections were removed from the product prior to washing in order to avoid any potential for different materials within printed sections contaminating the plain fabric with NPEs during the washing process.

Following a single wash, the fabric was dried and then a section of the fabric was isolated from the product and the concentration of NPEs was determined using an identical method to that described in Part 1.

Interspersed within the run of washes, two blank samples (plain fabric containing <1 mg/kg NPEs) were washed and subsequently analysed for their NPE content, in order to verify that the washing process did not result in contamination of samples.

Results and discussion

Table 6 presents the concentration of NPEs in sections of unwashed fabric and washed fabric for each product. The results for the unwashed fabric samples were determined for a portion isolated from each product without any other treatment (as presented in Part 1). Subsequently, the concentration of NPEs in washed fabric was determined in a separate portion isolated from the product after a single wash. For each product, the comparison between concentrations in washed and unwashed fabric is based upon total NPE concentrations determined for these two separate sections isolated from a single item.

Table 6. Concentrations of NPEs in washed fabric samples, and comparison with concentrations determined in a portion of unwashed fabric from the same product (as presented in Section 1). Limit of quantification = 1 mg/kg.

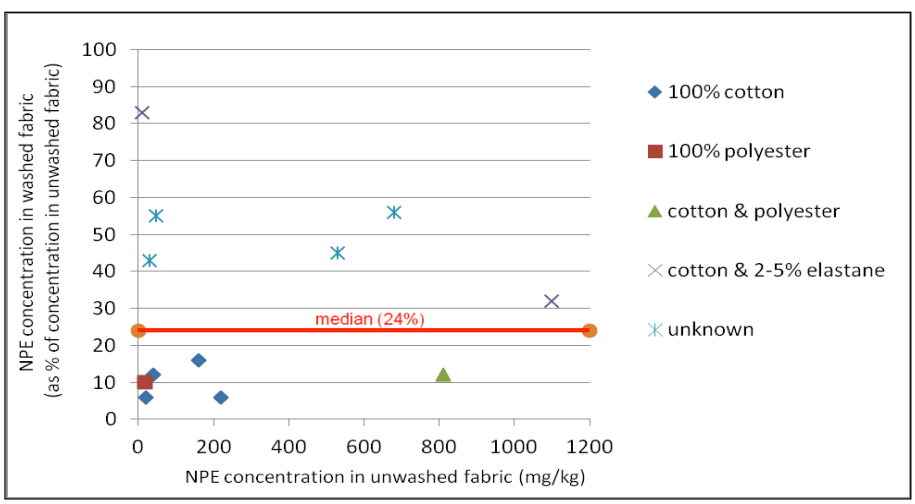
Sample code	Manufacturing brand	NPE concentration (mg/kg)		NPE conc. in washed sample as % of conc. in unwashed	Fraction of NPE apparently washed out (%)*	Kind of product	Fabric	Country of purchase	Country of manufacture
		Unwashed	Washed						
Plain fabric samples									
TX11061	G-Star RAW	11	9.1	83	17	Underwear	95% cotton 5% elastane	Netherlands	China
TX11003	Adidas	18	1.8	10	90	Polo shirt	100% polyester	Thailand	Thailand
TX11069	H&M	19	1.2	6	94	Polo shirt	100% cotton	China	China
TX11036**	Converse	30	13	43	57	Sneakers	Unknown	Spain	Vietnam
TX11074	Abercrombie & Fitch	39	4.6	12	88	T-shirt	100% cotton	Denmark	China
TX11014	Puma	47	26	55	45	Football shirt	Unknown	Switzerland	Turkey
TX11049	Calvin Klein	160	25	16	84	Pyjama trousers	100% cotton	Switzerland	Sri Lanka
TX11046	Ralph Lauren	220	14	6	94	T-shirt	100% cotton	Italy	Philippines
TX11039	Youngor	530	240	45	55	Polo shirt	Unknown	China	China
TX11019	Li Ning	680	380	56	44	Sport shirt	Unknown	Germany	China
TX11028	Nike	810	100	12	88	T-shirt	58% cotton 42% polyester	Russia	China
TX11073	Abercrombie & Fitch	1100	350	32	68	Jeans shorts	98% cotton 2% elastane	Japan	China
Plastisol printed samples									
TX11032	Converse	27000	12000	44	56	T-shirt	Unknown	Philippines	Philippines
TX11051	Kappa	470	430	91	9	T-shirt	Unknown	Thailand	Thailand

* Based on the assumption that the unwashed and washed portions from each item initially contained the same concentration of NPEs. Quoted values are the differences between concentrations in the washed and unwashed portions of each item, as a percentage of the concentration in the unwashed portion.
** Only the fabric portion of the sneaker was washed.

For all products investigated, the NPE concentrations in a washed portion were lower than concentrations in an unwashed portion of the same item, substantially lower in the majority cases.

For the plain fabric samples, the NPE concentrations in the washed portion were between 6% and 83% of the concentrations in the unwashed portion of the same product, with a median value of 24%. For all but one sample (TX11061), the washed portion concentration was less than 60% of the concentration for the corresponding unwashed portion, and for half the samples it was below 20% of the unwashed concentration.

Figure 1. Concentrations of NPEs in washed fabric (as % of concentration in unwashed fabric), for products with different levels of NPE in the unwashed products



The product with the smallest difference between levels in the washed and unwashed portions (TX11061, in which the washed portion contained NPEs at 83% of the level in unwashed portion) was also the product with the lowest initial level of NPEs (11 mg /kg NPEs in unwashed fabric). However, for two other items with NPE concentrations in unwashed fabric of below 20 mg/kg (TX11003 & TX11069), the level of NPEs in the washed portions was 10% or less of that in the respective unwashed portion. These results suggests that the smaller difference between levels of NPEs in washed and unwashed fabric for TX11061 was not due to the low level of NPEs in this product.

Indeed, for the plain fabric samples as a whole, the washed portion concentration (as a percentage of the unwashed value) was largely independent of the level of NPEs in the product. See Figure 1.

Though the data are limited, the results from this study suggest that the type of fabric that a product is made from is not a significant factor influencing the extent to which concentrations are lower in the washed portion compared to the unwashed portion. Values of 10% or less were found for one or more products composed of either 100% cotton or 100% polyester.

For the two plastisol printed samples, the results show a considerable difference between the effects of washing on the two samples. For the sample with the highest concentration of NPEs in the unwashed portion (TX11032, 27000 mg/kg), the concentration in the washed portion was 44% of this value. The sample with the lower concentration in the unwashed sample (TX11051, 470 mg/kg) gave a far smaller difference between the values for the washed and unwashed portions, with the concentration in the washed portion being 91% of that in the unwashed portion.

Conclusions

This study has demonstrated the widespread presence of NPEs within textile products, across almost all countries of manufacture, countries of purchase and brands 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 presence of NPE residues in a finished product available on the market strongly indicates their use during the manufacture of the product, but does not give information regarding the amount of NPEs used during its manufacture as residue levels will inevitably depend on a range of other factors, including the number and efficacy of wash cycles employed during product finishing. If NPEs are more efficiently washed out from materials during manufacture and finishing, this will inevitably result in a lower level of NPE residues in the final product, but at the same time would represent an increase in the quantities of NPEs released to water at source (in the country of manufacture). In the context of the current study, a finished article found to contain a low level of NPEs might nonetheless have been manufactured using higher quantities of NPEs than one found to contain higher residue concentrations, but with more of the NPEs being washed out before the product came to market. It also follows that, where NPEs were not identified for an individual item, the result does not demonstrate that the item was manufactured without the use of NPEs.

Information concerning the country of manufacture and sale, type of product and fabric and brand are provided for completeness and transparency, and should not be taken to imply that the results obtained are therefore representative of residue levels which may be expected for all such products within those categories. 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 perspective.

The possible presence of residues of other hazardous substances deriving from product manufacture was not investigated in this study

Analysis of washed samples

Assuming that the unwashed portion and the washed portion from each item initially contained the same concentration of NPEs, these results indicate that a single wash – using conditions intended to simulate standard domestic laundering – can wash out a substantial fraction of NPE residues present within textile products. For 11 of the 12 plain fabric samples tested in this way, the concentration of NPEs in washed fabric was less than 60% of the concentration found in unwashed fabric, and in half of the 12 samples the amount was less than 20%.

Therefore, using the same assumption, the results equate to between 17% and 94% of NPE residues being washed out from the fabric during a single wash, with more than 80% being washed out for half the samples.

Though limited in scope compared to the broad range of textile products on the market, the results also indicate that the extent to which NPEs are washed out under such conditions is largely independent of the initial level of NPE in the

unwashed product, and of the type of fabric that a product is made from. However, more extensive analysis of a wider range of products would be required in order to confirm the lack of such relationships.

In addition to the plain fabric samples, two samples of fabric that included a plastisol print were also investigated. The results demonstrate that it is possible for there to be a similar reduction in the concentration of NPEs in plastisol printed fabric following a single wash compared to plain fabrics. However, the results for one of the two plastisol printed samples indicate that NPE residues within plastisol printed fabrics may be less readily washed from an item in some cases.

As NPEs are readily water-soluble compounds, it can therefore be expected that they can be readily released from fabrics under standard washing conditions. However, as far as we are aware, this study is the first to report differences in the amounts of NPEs in fabric products before and after washing using simulated domestic laundering conditions.

It has previously been reported that NPEs can be detected in wash water following the washing of textile products under simulated domestic laundry conditions, though the amounts of NPEs in the wash water as a fraction of the total *quantity* of NPEs in the fabric prior to washing were not determined (Larsen *et al*. 2000).

Although the level of NPEs in any given article of clothing is relatively small, the sheer volume of clothing being sold and subsequently washed means that the total quantities of NPEs being released may be substantial.

Nonylphenol, formed from the partial breakdown of NPEs, continues to be detected in many rivers within the EU, often in relatively high concentrations compared to levels of other organic chemical pollutants monitored (EA 2011, Greenpeace 2010). Furthermore, monitoring data shows ongoing substantial releases of nonylphenol to surface waters within the EU, predominantly via urban wastewater and sewage treatment plants. Data, primarily that published through national and EU pollutant release and transfer registers (PRTRs), is relatively detailed for some EU member states, though few or no data are available for others (Greenpeace 2010).

It has been estimated that residues of NPEs and nonylphenol present in textile and leather goods in parts of Sweden were by far the most significant source of these chemicals entering wastewater treatment facilities in 2004, accounting for many tonnes a year. These calculations demonstrate the potential cumulative impact arising from the presence of relatively low concentrations of these chemicals in individual textile products (Månsson *et al.* 2008).

Despite requirements made in 2000 under the Water Framework Directive (WFD) that all emissions, discharges and losses of 'priority hazardous substances' be phased out within 20 years, which includes nonylphenol (EU 2001), inputs of nonylphenol to surface waters are ongoing within the EU.

Controls on the marketing and use of nonylphenol and NPEs have been in place within the EU since 2005, under which products containing greater than 0.1% of nonylphenol or NPEs may no longer be placed on the market, with some minor exceptions principally for closed loop industrial systems (EU 2003). However, restrictions on the import of textile products containing residues of NPEs from outside the EU have yet to be developed.

When restrictions on NPE residues in imported products are introduced, a maximum allowed limit of 100 mg/kg (0.01%) would fail to offer adequate protection, as the results from this study have demonstrated. Only 14 of the 52 products that tested positive for NPEs contained concentrations above 100 mg/kg, and yet the cumulative release of NPEs from products imported into the EU that contained levels of NPEs in a similar range to that found in this study would be considerable.

Therefore, a substantially lower limit than 100 mg/kg (0.01%) would need to be applied to offer adequate protection of European surface waters against inputs of NPEs and NP. Achieving this would require employing the lowest achievable level for verifying the presence of NPE residues in such products.

The Swedish government has recently submitted notifications of intention to propose restrictions on the sale of textile and leather articles containing residues of nonylphenol or NPEs within the EU (ECHA 2011). However, until adequate measures become effective, releases of NPEs from textiles and the resulting inputs of nonylphenol to surface waters within the EU will continue.

Similarly, in countries outside the EU, releases of NPEs and nonylphenol to surface waters will continue until measures are in place that prevent their manufacture, use and release, including as a result of the import of products containing residues of these substances. Such measures would include legislation, in conjunction with changes in company/brand policies, requiring the elimination of all uses and releases from their supply chains and their products.

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Table A1.1. Concentrations of NPEs in individual articles, by country of purchase and by brand

Country of purchase	NPE concentration (mg/kg)	Sample code	Brand
Argentina (4 of 4)	29	TX11050	Calvin Klein
	2.0	TX11027	Nike
	1.2	TX11015	Puma
	51	TX11045	Ralph Lauren
Austria (2 of 4)	<1	TX11009	Adidas
	<1	TX11042	H&M
	970	TX11054	Kappa
	12	TX11030	Nike
China (7 of 10)	<1	TX11001*	Adidas
	<1	TX11047	Calvin Klein
	19	TX11069	H&M
	9.8	TX11018	Li Ning
	<1	TX11022*	Nike
	210	TX11010	Puma
	2.2	TX11065	Uniqlo
	530	TX11039	Youngor
	190	TX11037	Youngor
	19	TX11069	Youngor
Czech Republic (1 of 4)	<1	TX11052	Kappa
	<1	TX11058	Lacoste
	<1	TX11025	Nike
	1.8	TX11006	Puma
Denmark (2 of 3)	39	TX11074	Abercrombie & Fitch
	<1	TX11034	Converse
	35	TX11043	Ralph Lauren
Finland (1 of 1)	660	TX11024	Nike
Germany (4 of 7)	<1	TX11002	Adidas
	140	TX11031	Converse
	<1	TX11060	G-Star RAW
	24	TX11055	Kappa
	680	TX11019	Li Ning
	<1	TX11076	Nike
	14	TX11011	Puma
Italy (3 of 4)	2.0	TX11008	Adidas
	240	TX11053	Kappa
	<1	TX11029	Nike
	220	TX11046	Ralph Lauren
Japan (3 of 5)	1100	TX11073	Abercrombie & Fitch
	9.1	TX11048	Calvin Klein
	<1	TX11040	Gap
	<1	TX11023	Nike
	8.7	TX11066	Uniqlo
Netherlands (3 of 5)	<1	TX11004	Adidas
	1.6	TX11033	Converse
	11	TX11061	G-Star RAW
	<1	TX11062	G-Star RAW
	21	TX11070	H&M
Norway (2 of 2)	14	TX11005	Adidas
	13	TX11063	G-Star RAW
Philippines (2 of 4)	27000	TX11032*	Converse
	<1	TX11057	Lacoste
	7.1	TX11021	Li Ning
	<1	TX11012	Puma
Russia (4 of 4)	5.0	TX11072*	H&M
	810	TX11028	Nike
	4.4	TX11017	Puma
	25	TX11068	Uniqlo
Spain (3 of 4)	30	TX11036	Converse
	41	TX11064*	G-Star RAW
	<1	TX11059	Lacoste
	12	TX11016	Puma
Sweden (0 of 2)	<1	TX11071	H&M
	<1	TX11013*	Puma
Switzerland (5 of 6)	1.1	TX11077	Adidas
	160	TX11049	Calvin Klein
	3.1	TX11078	H&M
	1.2	TX11026	Nike
	47	TX11014	Puma
	<1	TX11044	Ralph Lauren
Thailand (4 of 4)	18	TX11003	Adidas
	470	TX11051*	Kappa
	3.6	TX11056	Lacoste
	2.8	TX11020	Li Ning
UK (2 of 5)	18	TX11075	Abercrombie & Fitch
	<1	TX11007	Adidas
	17	TX11035	Converse
	<1	TX11041	Gap
	<1	TX11067	Uniqlo

* Indicates analysis of a section of fabric bearing a plastisol print

Table A1.2. Concentrations of NPEs in individual articles, by country of manufacture and by brand

Country of manufacture	NPE conc (mg/kg)	Sample code	Brand
Bangladesh (8 of 11)	41	TX11064*	G-Star RAW
	13	TX11063	
	<1	TX11060	
	21	TX11070	H&M
	3.1	TX11078	
	<1	TX11042	
	<1	TX11071	
	970	TX11054	Kappa
	4.4	TX11017	Puma
	51	TX11045	Ralph Lauren
	25	TX11068	Uniqlo
Cambodia (2 of 2)	18	TX11075	Abercrombie & Fitch
	1.2	TX11026	Nike
China (19 of 28)	1100	TX11073	Abercrombie & Fitch
	39	TX11074	
	14	TX11005	Adidas
	<1	TX11009	
	<1	TX11001*	
	<1	TX11002	
	<1	TX11007	
	<1	TX11047	Calvin Klein
	17	TX11035	Converse
	<1	TX11040	Gap
	11	TX11061	G-Star RAW
	19	TX11069	H&M
	24	TX11055	Kappa
	680	TX11019	Li Ning
	9.8	TX11018	
	7.1	TX11021	
	810	TX11028	Nike
	660	TX11024	
	<1	TX11022*	
	<1	TX11029	
	210	TX11010	Puma
	1.2	TX11015	
	<1	TX11044	Ralph Lauren
	8.7	TX11066	Uniqlo
	2.2	TX11065	
	530	TX11039	Youngor
	190	TX11037	
	19	TX11038	
Egypt (1 of 1)	9.1	TX11048	Calvin Klein
Indonesia (2 of 3)	2.0	TX11027	Nike
	<1	TX11012	Puma
	35	TX11043	Ralph Lauren
Malaysia (2 of 2)	2.8	TX11020	Li Ning
	12	TX11016	Puma
Pakistan (1 of 1)	240	TX11053	Kappa
Philippines (3 of 4)	1.1	TX11077	Adidas
	<1	TX11004	
	27000	TX11032*	Converse
	220	TX11046	Ralph Lauren
Sri Lanka (1 of 1)	160	TX11049	Calvin Klein
Thailand (5 of 6)	18	TX11003	Adidas
	2.0	TX11008	
	29	TX11050	Calvin Klein
	470	TX11051*	Kappa
	3.6	TX11056	Lacoste
	<1	TX11023	Nike
Tunisia (0 of 1)	<1	TX11062	G-Star RAW
Turkey (5 of 9)	1.6	TX11033	Converse
	<1	TX11034	
	5.0	TX11072*	H&M
	12	TX11030	Nike
	<1	TX11025	
	<1	TX11076	
	47	TX11014	Puma
	1.8	TX11006	
	<1	TX11013*	
Vietnam (3 of 6)	140	TX11031	Converse
	30	TX11036	
	<1	TX11041	Gap
	<1	TX11052	Kappa
	14	TX11011	Puma
	<1	TX11067	Uniqlo
Unknown (3 of 3)	<1	TX11057	Lacoste
	<1	TX11058	
	<1	TX11059	

* Indicates analysis of a section of fabric bearing a plastisol print

Table A1.3. Concentrations of NPEs in individual articles by brand, with the kind of product and fabric where known

Brand	NPE conc. (mg/kg)	Sample code	Country of purchase	Country of manufacture	Kind of product	Fabric
Abercrombie & Fitch	1100	TX11073	Japan	China	Jeans shorts	Cotton + 2% elastane
	39	TX11074	Denmark	China	T-shirt	Cotton
	18	TX11075	UK	Cambodia	T-shirt	Cotton
Adidas	18	TX11003	Thailand	Thailand	Polo shirt	Polyester
	14	TX11005	Norway	China	Dress	Cotton
	2.0	TX11008	Italy	Thailand	Football shirt	Polyester
	1.1	TX11077	Switzerland	Philippines	Tracksuit trousers	-
	<1	TX11001*	China	China	T-shirt	-
	<1	TX11002	Germany	China	Football shirt	Polyester
	<1	TX11004	Netherlands	Philippines	Tracksuit jacket	-
	<1	TX11007	UK	China	Sweatshirt	-
	<1	TX11009	Austria	China	Tracksuit trousers	-
Calvin Klein	160	TX11049	Switzerland	Sri Lanka	Pyjama trousers	Cotton
	29	TX11050	Argentina	Thailand	Underwear	Cotton + 5% elastane
	9.1	TX11048	Japan	Egypt	Underwear	Nylon + 28% elastane
	<1	TX11047	China	China	Underwear	Cotton
Converse	27000	TX11032*	Philippines	Philippines	T-shirt	-
	140	TX11031	Germany	Vietnam	Sneakers	-
	30	TX11036	Spain	Vietnam	Sneakers	-
	17	TX11035	UK	China	Sneakers	-
	1.6	TX11033	Netherlands	Turkey	T-shirt	Cotton
	<1	TX11034	Denmark	Turkey	T-shirt	Cotton
G-Star RAW	41	TX11064*	Spain	Bangladesh	T-shirt	Cotton
	13	TX11063	Norway	Bangladesh	T-shirt	Cotton
	11	TX11061	Netherlands	China	Underwear	Cotton + 5% elastane
	<1	TX11060	Germany	Bangladesh	T-shirt	Cotton
	<1	TX11062	Netherlands	Tunisia	Jeans	Cotton
Gap	<1	TX11040	Japan	China	T-shirt	Cotton
	<1	TX11041	UK	Vietnam	T-shirt	Cotton
H&M	21	TX11070	Netherlands	Bangladesh	Tank top	Cotton
	19	TX11069	China	China	Polo shirt	Cotton
	5.0	TX11072*	Russia	Turkey	T-shirt	Cotton + 13% viscose
	3.1	TX11078	Switzerland	Bangladesh	Shirt	Cotton
	<1	TX11042	Austria	Bangladesh	T-shirt	Cotton
	<1	TX11071	Sweden	Bangladesh	Sweatshirt	Cotton
Kappa	970	TX11054	Austria	Bangladesh	T-shirt	Cotton
	470	TX11051*	Thailand	Thailand	T-shirt	-
	240	TX11053	Italy	Pakistan	Tracksuit	Polyester
	24	TX11055	Germany	China	Football shirt	Polyester
	<1	TX11052	Czech Republic	Vietnam	Sweatshirt	-
Lacoste	3.6	TX11056	Thailand	Thailand	Polo shirt	Cotton + 6% elastane
	<1	TX11057	Philippines	unknown	Polo shirt	Cotton
	<1	TX11058	Czech Republic	unknown	Polo shirt	Cotton
	<1	TX11059	Spain	unknown	Polo shirt	Cotton
Li Ning	680	TX11019	Germany	China	Sport shirt	-
	9.8	TX11018	China	China	Polo shirt	54% Cotton + 46% polyester
	7.1	TX11021	Philippines	China	T-shirt	Polyester
	2.8	TX11020	Thailand	Malaysia	Polo shirt	Polyester + 12% elastane
Nike	810	TX11028	Russia	China	T-shirt	58% Cotton + 42% polyester
	660	TX11024	Finland	China	T-shirt	58% Cotton + 42% polyester
	12	TX11030	Austria	Turkey	T-shirt	Cotton
	2.0	TX11027	Argentina	Indonesia	Tracksuit jacket	65% cotton, 31% polyester, 4% elastane
	1.2	TX11026	Switzerland	Cambodia	Polo shirt	Polyester + 12% elastane
	<1	TX11022*	China	China	T-shirt	-
	<1	TX11023	Japan	Thailand	Sport shirt	Polyester
	<1	TX11025	Czech	Turkey	T-shirt	Polyester
	<1	TX11029	Italy	China	T-shirt	Cotton
	<1	TX11076	Germany	Turkey	Tank top	Cotton
Puma	210	TX11010	China	China	T-shirt	-
	47	TX11014	Switzerland	Turkey	Football shirt	-
	14	TX11011	Germany	Vietnam	Sport shorts	Polyester
	12	TX11016	Spain	Malaysia	Tracksuit jacket	Polyester
	4.4	TX11017	Russia	Bangladesh	T-shirt	-
	1.8	TX11006	Czech	Turkey	Football shirt	80% Cotton + 20% polyester
	1.2	TX11015	Argentina	China	T-shirt	Cotton
	<1	TX11012	Philippines	Indonesia	Sport shirt	Polyester + 9% elastane
	<1	TX11013*	Sweden	Turkey	T-shirt	-
Ralph Lauren	220	TX11046	Italy	Philippines	T-shirt	Cotton
	51	TX11045	Argentina	Bangladesh	Jeans	Cotton
	35	TX11043	Denmark	Indonesia	Polo shirt	Cotton
	<1	TX11044	Switzerland	China	Polo shirt	Cotton
Uniqlo	25	TX11068	Russia	Bangladesh	Jeans	Cotton
	8.7	TX11066	Japan	China	Polo shirt	65% cotton, 30% polyester, 5% elastane
	2.2	TX11065	China	China	T-shirt	-
	<1	TX11067	UK	Vietnam	Jeans	Cotton + 2% elastane
Youngor	530	TX11039	China	China	Polo shirt	-
	190	TX11037	China	China	Polo shirt	-
	19	TX11038	China	China	Shirt	-

* Indicates analysis of a section of fabric bearing a plastisol print