User Guide

Classification and Risk Assessment of Textiles for Material Recycling

Results from a research project financed by Vinnova
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1 Foreword

This report is delivered as a result of the Vinnova funded project Classification and risk assessment of textiles for material recycling. The project is a cooperative effort involving all partners in the project consortium; RISE IVF, Naturvårdsverket, SIS, Innovatum, Avfall Sverige, Renova, Texaid, Myrorna, Göteborgs Stad, Vänersborgs Kommun och Naturskyddsföreningen.

Target groups

According to the scope of this project, the main target groups are end-users of recycled textile material. However, as the accessible information in regard to chemical content of sorted, post-consumer textile in bulk is very limited, the results of this project will be, and has been, spread as widely as possible and the content of this guide is open to all. Actors such as brands, recyclers, sorting facilities and charities, authorities and professionals within public procurement are in focus.

2 Introduction

When working with textile recycling there are many technologies that will need to be utilized, mechanical as well as chemical. – fiber to fiber and fiber to other material categories. There are several options available when discussing material recycling of textiles. Recycling of textile materials into new products within the same material category is desired, but textiles for material recycling can also be utilized as raw material for production of new plastics, composite or nonwoven products. One very important issue in material recycling of textile is the question of possible chemical content in the material and the implications that this may have on the products made from recycled textile. Today there is information available about listed chemicals with textile relevance in different reports, for example the report 6/14 from Swedish Chemicals Agency. The purpose with this guide is to convey the results of practical analyses of chemical content of collected postconsumer textile where the intention is to use the material as feedstock in recycling processes. In addition to increasing the knowledge of the actual chemical content of defined textile materials in bulk volumes, the aim is also to link the obtained results to the theoretical reasoning of substances that would be a suspected content in certain material qualities to actual findings and to recommend analysis of bulk qualities to ensure quality in terms of chemical content. This project has not included any other parameters, such as fiber length distribution, in its scope.

In 2015, on behalf of the government, RISE IVF participated and produced the report Chemicals in textiles – Risks to human health and the environment, together with the Swedish Chemicals Agency. The report points out that substances used in production, for example in surface treatment, may remain in the final product, intentionally or unintentionally, and it is difficult to know exactly which substances remain and in what concentration. Many of the chemical substances used in textile manufacturing can be harmful to human health and/or the environment or disturb subsequent processes, such as recycling processes. Textiles that are collected today and enter a future recycling system have often been placed on the market several years before and may therefore have been produced prior to the enforcement date of current law requirements. In textile manufacturing, a variety of chemicals are added to give textiles different properties, like dyeing into a specific color or to create a dirt and water repellent surface of a fabric. Some of the chemicals are washed out from the textiles before they reach the consumer, but sometimes there are chemicals left in the textile material when it reaches the

consumer. The chemicals are gradually leached out as the products are used and worn out, however there is no guarantee that all chemicals are washed out from the textile\textsuperscript{2}. Consequently, it is important to know what chemicals remain in the material before using them as feedstock in new products. About 3500 substances have been identified as relevant for use in textiles. However, the actual use and level of presence in textiles has not been verified. Some chemicals affect people and the environment through the whole life cycle, therefore it is not only in textile recycling the use of chemicals and the handling of chemicals have been highlighted\textsuperscript{1}. Databases are available where chemicals with textile relevance are listed and the purpose of this guide, as previously described, is to convey the results of practical analyses of post-consumer textile regarding their chemical profile, linking this to the theoretical model of which substances that are relevant for that category. Furthermore, the project aim has been to link the chemical content to textile categories in a classification system connected to recommendation in regard to material assessment, see Figure 1 for the model which is the basis for this project and the analysis work.

The current work to produce a user guide within this project is based on the background information from the aforementioned report\textsuperscript{1, 2}. In dialogue with industry intending to use recycled textile as raw material, it is evident that the issue of chemical content is of common interest, irrespective of sector. Insufficient knowledge and information about composition and content of textile products for recycling is a challenge and a hurdle in regard to enabling high-value recycling and to establish trust in recycled feedstock. The work performed in this project is based on mechanical recycling, which is to be considered as the worst-case scenario as this technology does not, and cannot, sort out or filter out any chemicals. In other words, what you introduce into the process will remain in the product – in this case recycled textile fiber. In a circular economy, we need to retain control of our recycled materials and the resulting products, where it is the legislation around the resulting product that must be fulfilled. Again, in a case where recycled textile fiber is produced and used as raw material in a garment at 50\% recycled content, this is to be considered as the most difficult case when considering legislation around chemical content, as compared to using the recycled fiber in a nonwoven for the automotive industry to give an example.

3 Methodology

3.1 Sample preparation

The materials selected for analyses were sorted and prepared using a method developed within the project. The first step in the method is to sort the garments into subcategories depending on specific fiber type and use of the textile, for example workout clothes and everyday garments was sorted separately. When all garments are sorted, they are weighted, and the number of individual items counted for each category. The garments were then washed in an industrial washing machine at 40 or 60 degrees Celsius, depending on material type, and dried in a tumble dryer at maximum 50 degrees.

3.2 Mechanical processing

All types of plastic prints, zippers, tags, etc. were removed from the garments. The garments were then cut in smaller pieces in a cutting machine. At a size of 10 x 10 centimeters, the textile pieces were mixed to ensure a homogeneous textile mix. The cut textile was then processed in a textile tearing machine. The textile tearing machine available at RISE IVF consists of one opening cylinder (8 mm teeth) and three tear cylinders (4 mm teeth). Commercial units generally have 6-9 tear cylinders; however this can be accomplished by allowing the material to pass the three tear cylinders one or two more times. This assessment is made on a case-by-case basis by manually assessing the quality of the outgoing material. To ensure a high homogeneity of the material before analysis, it was mixed in a large cylinder using compressed air. Samples (3 parallels for each analysis) were collected from each fraction and then the material was ready for chemical analysis.
3.3 Materials
Since the main goal in the project was to analyze different main textiles and their chemicals, non-textile parts like zippers, prints and laundry instruction tags were removed prior to processing and analysis. Prints and laundry instruction tags can contain other chemicals than the main textile material and could therefore interfere with the chemical analysis of the main textile material. Metallic parts must be removed before further processing since they can damage the tearing equipment.

3.4 Sample categories
Selected samples for analysis were divided into categories according to the tables below. The project work was divided into two large blocks, below referred to as Analysis part 1 and Analysis part 2.

Table 1. Analysis part 1

<table>
<thead>
<tr>
<th>Polyester</th>
<th>Cotton</th>
<th>Polyester/Cotton</th>
<th>Polyamide (PA6, PA6.6 with lycra)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind and workout jackets</td>
<td>T-shirts and hoodies</td>
<td>Work pants</td>
<td>Workout clothes</td>
</tr>
<tr>
<td>Workout clothes</td>
<td>Bedlinen (sheets)</td>
<td></td>
<td>Swimwear</td>
</tr>
<tr>
<td>Mixed garments</td>
<td>Shirts</td>
<td></td>
<td>Pantyhose</td>
</tr>
<tr>
<td></td>
<td>Denim (max 3% elastane)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Analysis part 2

<table>
<thead>
<tr>
<th>Acrylic/wool blends</th>
<th>Wool blends</th>
<th>Cotton blends</th>
<th>Polyester/Cotton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knitted garment</td>
<td>Shredded material</td>
<td>Mixed garments</td>
<td>Mixed garments</td>
</tr>
</tbody>
</table>

4 Analytical set up

4.1 Spot-checks
The procedure when performing spot-checks can vary, but it is often based on a company’s request to check their product for legal requirements or for fulfillment for their own “RSL-list” (Restricted Substance List). In general, the tests are chosen based on evaluation of the product
and depending on special demands and area of use, but also color and material of the product. Taking these aspects into consideration, different chemical analyses will be recommended. Of course, recommendations also consider earlier findings in similar materials or products.

4.2 Identified risk chemicals

There are several studies that have identified particularly hazardous chemicals with textile relevance. These studies identified a number of groups of particularly hazardous substances that may in some way remain in used textiles. These known groups of concern include:

- Per- and polyflouric substances
- Halogenated flame retardants
- Toxic softeners
- Toxic metals
- Toxis colourants and pigments
- CMR biocides
- CMR solvents
- Traces of toxic degradation products such as polycyclic hydrocarbons (PAH), dioxins and dibenzofuranes

The below chemical groups were selected for analysis within the project. The groups were selected based on relevance (function in finished material, occurrence described in literature and experiential occurrence) in the specific materials. For the full list of compounds see Appendix 1.

- APEO and AP
- Dimethyl fumarate
- PFC’s
- Allergenic disperse dyes
- Arylamines derived from azo colorants
- Chlorinated benzenes and toluenes
- XRF screening – Pb, Cd, Ni, Cr, Br, Hg, Sb, Ti, Cl
- Extracted metals (if positive result at XRF-screening)
- Organic tin compounds
- Chlorinated phenols
- PAH
4.2.1 APEO and AP

These chemicals are used as dispersing and emulsifying agents in textile chemicals as well as impregnation agents in printing pastes. Also used as lubricants in leather.

Alkylphenol ethoxylates (APEO) and alkylphenols were determined according to Oeko-TEX®. The analysis started with an extraction with organic solvent in an ultrasonic bath and was followed by detection with LC-MS/MS and GC-MS. The sample weight in the analysis was 1.0 g. To quantify NP(EO)1-20 a technical mixture named Igepal CO-720/Imbenti-N/060 was used. OP(EO)1-20 was quantified using the technical mixture Triton X-45/Igepal CA-720. The other analysed compounds were quantified using certified reference materials. The analysed compounds are: 4-nonylphenol ethoxylate (NPEO), degrees of ethoxylation: 1-20, analysed with LC-MS/MS, 4-octylphenol ethoxylate (OPEO), degrees of ethoxylation: 1-20, analysed with LC-MS/MS and 4-nonylphenol, 4-octylphenol, 4-pentylphenol and 4-heptylphenol analysed with GC-MS. The limit of quantification was set to 20 mg/kg for NP(EO)1-20 and OP(EO)1-20 and 2.5 mg/kg for 4-nonylphenol, 4-octylphenol, 4-pentylphenol and 4-heptylphenol.

4.2.2 Dimethyl fumarate (DMFu)

DMFu are used to counteract fungus growth in clothes, shoes and other leather items. DMFu can e.g. be found in silica gel bags but is also applied on the product both as a powder and in tablet form.

Dimethylfumarate (CAS no 624-49-7) was determined according to Oeko-TEX®. Extraction with organic solvent in an ultrasonic bath was the starting point in the analysis, followed by detection with GC-MS. The sample weight in the analysis was 4.0 g. Quantification was performed with certified reference material and the limit of quantification was set to 0.02 mg/kg.

4.2.3 PFC’s

Used as an impregnation agent in leathers and textiles and as surfactant in fire-fighting foams, cleaning agents and in metal plating baths.

Perfluorinated compounds (PFC) were determined according to Oeko-TEX®. The sample weight in the analysis was 2.0 g. The analysis starts with an extraction with organic solvent in an ultrasonic bath, followed by detection with LC-MS/MS. The quantification was done with certified reference material. The quantification limit was 0.8 µg/m2 for PFOA, PFOS, PFOSF, PFOSA, N-Me-FOSA, N-Et-FOSA, N-Me-FOSE and N-Et-FOSE. 0.005 mg/kg for PFHpA, PFNA, PFDA, PFUdA, PFDoA, PFTrDA, PFTeDA, PFBA, PFPeA, PFHxA, PF-3,7-DMOA, PFBS, PFHxS, PFHpS, PFDS, 7PFHpA, 4HPFU nA, 1H, 1H, 2H and 2H-PFOS. And 0.05 mg/kg for 4:2 FTOH, 6:2 FTOH, 8:2 FTOH, 10:2 FTOH, 6:2 FTA, 8:2 FTA and 10:2 FTA.
4.2.4 Allergenic disperse dyes

*Used to dye textile and leather imitation goods especially polyester.*

Allergenic disperse dyes, quinoline and restricted CMR dyes was determined according to OEKO-TEX®. Used sample weight was 1.0 g. Extraction with organic solvent was done using a Dionex ASE350, followed by detection with LC-MS/MS. Quantification with certified reference material and the limit of quantification was 10 mg/kg.

4.2.5 Arylamines derived from azo colorants

*Certain azo dyes can degrade to form carcinogenic arylamines.*

Presence of certain arylamines derived from azo colorants was determined according to SS-EN 14362-1:2017, detection of the use of certain azo colorants accessible with and without extracting the fibres. Used sample weight was 1.0 g. LC-MS/MS was used for detection, and quantification was set with GC-MS. Quantification with certified reference material and the limit of quantification was 5.0 mg/kg.

4.2.6 Chlorinated benzenes and toluenes

*Used as solvents in dyeing of synthetic fibres and in printing. Also used as moth-proofing agent in textiles and for the manufacture of silk and pearls.*

Chlorinated benzenes and toluene’s were determined according to OEKO-TEX®. Extraction with organic solvent followed by detection with GC-MS/MS. Quantification with certified reference material and the limit of quantification was 0.1 mg/kg.

4.2.7 XRF screening – Pb, Cd, Ni, Cr, Br, Hg, Sb, Ti, Cl

Lead salts are used as additives in plastics as stabilizers to increase the service of life of the material. May be used in paint and in colored plastic material and as metallic surface coating of buttons and accessories. Cadmium can occur in pigmented plastisol prints (not in scope). Nickel is often used to improve alloys used in clothing accessories such as zippers, buttons and rivets (not in scope). Nickel may also be used in metal complex dyes. Chromium salts are used for preparation and finishing of acid dyes on silk and wool. Potassium dichromate is used for oxidation of vat and sulphur dyes. Used for finishing of direct dyes to improve their wash fastness. Presence of bromine can be an indication that Brominated flame retardants have been used. Phenylmercury compound are used as catalysts in the production of polyurethane coatings, adhesives, sealants and elastomers. Antimony is used as a flame retardant (mainly in combination with other halogenated flame retardants) and as a catalyst for the production of polyester fibres. The latter application dominates by far. TiO(2) is used in textiles because of its UV-absorbing properties and as pigment (opacity). Chlorine and its compounds are used in the paper and textile industries for bleaching. Different chlorinated compounds may have a variety of different functions in material, as plasticizers, as flame retardants, as biocides etc.
4.2.8 Extractable metals (performed at positive findings in XRF-screening)

The coming regulation focusing on CMR substances in textiles, include restriction of heavy metals. Since the restriction do not exclude recycled material, analysis of extractable metals were performed. OEKO-TEX also regulate these metals within the certifications scope. Extractable metals were determined according to OEKO-TEX®. Analysed metals in mg/kg were Antimony (Sb), Arsenic (As), Lead (Pb), Cadmium (Cd), Chromium (Cr), Cobalt (Co), Copper (Cu), Nickel (Ni), Mercury (Hg), Barium (Ba) and Selenium (Se). The sample weight was 2.0 g. Extraction with artificial acidic perspiration solution was made according to ISO 105-E04, followed by detection with ICP-OES. Quantification limit was set with certified reference material and the limits of quantification (LOQ) are presented in the table below.

<table>
<thead>
<tr>
<th>Metals</th>
<th>Sb</th>
<th>As</th>
<th>Pb</th>
<th>Cd</th>
<th>Cr</th>
<th>Co</th>
<th>Cu</th>
<th>Ni</th>
<th>Hg</th>
<th>Ba</th>
<th>Se</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOQ</td>
<td>0.3</td>
<td>0.1</td>
<td>0.1</td>
<td>0.05</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.02</td>
<td>0.3</td>
<td>0.3</td>
</tr>
</tbody>
</table>

4.2.9 Organic tin compounds

**Organotin compounds are used in consumer products as stabilizers, catalysts or biocides.**

Organic tin compounds were determined according to OEKO-TEX®. The sample weight was 1.0 g. Extraction was done with organic solvent and derivatization with sodium tetraethylborate, followed by detection with GC-MS. Quantification was set with certified reference material. These compounds relate to plastics and have been included to validate that all traces related to prints have been removed.

4.2.10 Chlorinated phenols

**Chlorinated phenols are commonly used as herbicides, pesticides and disinfectants.**

Pentachlorophenol, tetrachlorophenols, trichlorophenols, dichlorophenols, monochlorophenols orthophenylphenol and phenol were determined according to OEKO-TEX®. The sample weight was 5.0 g. The extraction was made with organic solvent using a Dionex ASE350, followed by detection with GC-MS. Quantification was done with certified reference material. Limit of quantification was 0.02 mg/kg for pentachlorophenol, tetrachlorophenols, trichlorophenols, dichlorophenols and monochlorophenols. For orthophenylphenol the limit was 0.2 mg/kg and for phenol 4 mg/kg.
4.2.11 PAH

PAHs are not synthesized chemically for industrial purposes. The major source of PAHs is the incomplete combustion of organic material such as coal, oil and wood. PAHs may be found as impurities in materials.

Polycyclic aromatic hydrocarbons (PAH) were determined according to OEKO-TEX®. The sample weight was 1.0 g. The extraction was done with organic solvent in an ultrasonic bath, followed by detection with GC-MS. Quantification was set with certified reference material with a limit of quantification at 0.20 mg/kg.

4.3 Analytical tools

4.3.1 XRF-screening (X-ray fluorescence)

The concentration of some elements can be checked rapidly with XRF. A handheld XRF can quickly give information about metal - and element content in textiles down to around 100 ppm.

Screening for Cadmium (Cd), Lead (Pb), Bromine (Br), Nickel (Ni), Chromium (Cr), Mercury (Hg), Antimony (Sb), Titanium (Ti) and Chlorine (Cl) was performed with an X-ray fluorescence (XRF) spectroscopy ED-XRF, Niton XL3t (Holger Andreasen AB) on the textile fractions. If the result of the elements were positive, the materials were analysed on ICP (Inductively Coupled Plasma)

4.3.2 ICP (Inductively Coupled Plasma)

ICP has better accuracy than XRF on inorganic materials and was used on materials that had a positive result in the XRF-screening.

Extractable metals - Cadmium (Cd), Lead (Pb), Nickel (Ni), Chromium (Cr), Mercury (Hg), Antimony (Sb), Titanium (Ti), Arsenic (As), Cobalt (Co), Copper (Cu), Barium (Ba) and Selenium (Se) were analysed using Inductively coupled plasma - optical emission spectrometry (ICP-OES), model Avio200 manufactured by PerkinElmer. The samples were extracted with a synthetic sweat solution before analysis in ICP-OES.

4.3.3 LC-MS/MS

Liquid chromatography–mass spectrometry is an accurate analytical method that combines the features of liquid chromatography and mass spectrometry to identify different substances within a test sample.

Alkylphenol ethoxylates, Perfluorinated compounds (PFC’s), Allergenic disperse dyes and Cancerogenic arylamines were analysed using Liquid Chromatography-Mass Spectrometry (LC—MS/MS), LC model 1200, MS/MS model 6420, manufactured by Agilent.
4.3.4 GC/MS
Gas chromatography–mass spectrometry is an accurate analytical method that combines the features of gas-chromatography and mass spectrometry to identify different substances within a test sample. Alkylphenols (AP), Dimethylfumarate (DMFu), Perfluorinated compounds (PFC’s), Organotin compounds, Chlorinated phenols and Polyaromatic hydrocarbons (PAH) were analysed using Gas Chromatography-Mass Spectrometry (GC--MS), GC model 7890B, MS model 5977B, manufactured by Agilent. Determination of chlorinated benzenes and toluenes were performed on GC-MS by a subcontractor laboratory - Hohenstein Textile Testing Institute GmbH & Co. KG.

5 Policies related to textile chemicals

5.1 POPs regulation (EC) 2019/1021, on persistent organic pollutants
In Stockholm 2001, the UNs Convention a global action against persistent organic pollutants was taken. The convention is implemented in the EU legislation as regulation (EC) no 2019/1021 (former EC no 850/2004), the POPs regulation. The regulation restricts, substances such as pesticides (DDT, lindan etc), brominated flame retardants (PBDE and HBCDD), PFOS and SCCPs. Substances that pose a risk of being used in, or contaminate, textile material and are regulated in POPs are listed in Table 2.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Regulated limit (by weight)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloinated pesticides and insecticides (DDT, chlordane, hexachlorocyclohexanes)</td>
<td>Ban, Ban</td>
<td>The manufacturing, placing on the market and use of substances in mixtures or in articles, shall be prohibited.</td>
</tr>
<tr>
<td>Chlorinated pesticides and insecticides (Endosulfan, Polychlorinated naphthalene)</td>
<td>Ban, Ban</td>
<td>Placing on the market and use of articles already in use before or on 10 July 2012 containing endosulfan shall be allowed.</td>
</tr>
<tr>
<td>Hexabromcyclohexane (HBCDD)</td>
<td>0.01, 100</td>
<td>Tetra-, penta-, hexa-, hepta- and decaBDE, shall apply to the sum of the concentration of those substances up to 500 mg/kg where they are present in mixtures or articles</td>
</tr>
<tr>
<td>Sum of tetra, penta, hexa, hepta and decaDBE</td>
<td>0.05, 500</td>
<td>Textiles or other coated materials lower than 1 µg/m2 of the coated material.</td>
</tr>
<tr>
<td>Perfluorooctane sulfonic acid and its derivatives (PFOS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short chain chloroparaffines (SCCP)</td>
<td>0.15, 1500</td>
<td>In the article.</td>
</tr>
</tbody>
</table>
5.2 REACH regulation (EC) no 1907/2006, concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)

REACH (EC 1907/2006) aims to improve the protection of human health and the environment through the better and earlier identification of the intrinsic properties of chemical substances. Substances with unacceptable risks are restricted. Certain hazardous substances called SVHC (Substances of Very High Concern) shall not be used in the EU unless an authorisation has been granted.

Substances that pose a risk of being used in, or contaminated, textile material and are regulated in REACH annex XVII, are listed in Table 3.

In addition to the regulated substances, Allergenic disperse dyes were analyzed, since textile industry organizations and retailers have long demanded these substances. Table 4 lists SVHCs\(^3\) (belonging to similar chemical groups) on the candidate list for authorisation, that also pose a risk of being used in, or contaminated the material. Presence of SVHCs substances in the material triggers information duty (according to article 33 in REACH) and/or authorisation (annex XIV of REACH).

Table 5. Relevant regulated substances according to REACH regulation 1907/2006

<table>
<thead>
<tr>
<th>Substance</th>
<th>Regulated limit (by weight)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tris (2,3 dibromopropyl) phosphate</td>
<td>ban</td>
<td>Shall not be used in textile articles, such as garments, undergarments and linen, intended to come into contact with the skin. The substance was last being sold in the late 1970s</td>
</tr>
<tr>
<td>Tris(aziridinyl)phosphinoxide</td>
<td>ban</td>
<td>Shall not be used in textile articles, such as garments, undergarments and linen, intended to come into contact with the skin. The substance have been phased out in the textile industry</td>
</tr>
<tr>
<td>Polybromobiphenyls; Polybrominatedbiphenyls (PBB)</td>
<td>ban</td>
<td>Shall not be used in textile articles, such as garments, undergarments and linen, intended to come into contact with the skin.</td>
</tr>
<tr>
<td>Mercury compounds</td>
<td>Ban</td>
<td>Shall not be used in the impregnation of heavy-duty industrial textiles and yarn intended for their manufacture</td>
</tr>
<tr>
<td>Organostannic compounds, Dioctyltin (DOT) compound</td>
<td>0.1 (by weight of tin) 1000 (by weight of tin)</td>
<td>Shall not be used in textile articles intended to come into contact with the skin</td>
</tr>
<tr>
<td>Arylamines degradable from azocolourants and azodyes</td>
<td>0.003 300</td>
<td>Shall not be used, in textile and leather articles which may come into direct and prolonged contact with the human skin or oral cavity</td>
</tr>
<tr>
<td>Nonylphenol ethoxylates (NPE)</td>
<td>0.01 100</td>
<td>Shall not be placed on the market after 3 February 2021 in textile articles(^4)</td>
</tr>
</tbody>
</table>

\(^3\) SVHC (substances of very high concern), where authorisation will be needed for the use of these substances within EU. Before authorisation come into force the SVHC are on the candidate list for authorisation, and information shall be given if the SVHC content is above 0.1 w% in the material (information duty).

\(^4\) ‘Textile article’ means any unfinished, semi-finished or finished product which is composed of at least 80 % textile fibres by weight, or any other product that contains a part which is composed of at least 80 % textile fibres by weight, including products such as clothing, accessories, interior textiles, fibres, yarn, fabrics and knitted panels. The regulation refer to textiles which can reasonably be expected to be washed in water during their normal lifecycle, in concentrations equal to or greater than 0.01 % by weight of that textile article or of each part of the textile article.
Shall not apply to the placing on the market of second-hand textile articles or of new textile articles produced, without the use of NPE, exclusively from recycled textiles.

Perfluorooctanoic acid (PFOA) and its salts. 0.025 Shall not, from 4 July 2020, be used in the production of, or placed on the market in an article, in a concentration equal to or above 25 ppb of PFOA including its salts or 1 000 ppb of one or a combination of PFOA-related substances. 5

DMFu 0.00001 0.1 Shall not be used in articles of part thereof

CMR substances (various) listed in appendix 2 various various CMR substances shall not be placed on the market after 1 November 2020 in clothing or related accessories; textiles other than clothing which, under normal or reasonably foreseeable conditions of use, come into contact with human skin to an extent similar to clothing; and footwear;

Table 6. Relevant substance groups on the candidate list (SVHC substances for authorisation)

<table>
<thead>
<tr>
<th>Substance</th>
<th>Regulated limit (by weight)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAHs</td>
<td>0.1 1000</td>
<td>In addition to those PAHs regulated in accordance with REACH, annex 17</td>
</tr>
<tr>
<td>APEOs</td>
<td></td>
<td>In addition to NPEO regulated in accordance with REACH, annex 17</td>
</tr>
<tr>
<td>PFASs</td>
<td>In addition to those PFASs regulated in accordance with REACH, annex 17</td>
<td></td>
</tr>
<tr>
<td>Hexabromcyclododecane (HBCDD)</td>
<td>0.1 1000</td>
<td>SVHC (authorisation and information duty)</td>
</tr>
</tbody>
</table>

6 Voluntary schemes

6.1 OEKO-TEX®
OEKO-TEX® is an association of textile research and test institutes located in Europe and Japan. They offer a variety of certifications in different areas with different approaches. Since this user guide have focused on chemicals in textile products the following description only applies to STANDARD 100 by OEKO-TEX®. Within the certification OEKO-TEX® consider numerous regulated and non-regulated substances, which may be harmful to human health. In many cases the limit values for the STANDARD 100 go beyond national and international requirements. In this extended user guide the limits for STANDARD 100 have been used 6.

7 Analytical results
NPEO were found in 9 out of 20 fractions but only two of the fractions had values above OEKO-TEX limit values of 100 mg/kg. Both fractions were wool mixtures (WO/AC and WO/other fibres). None of the fractions contained NPEO values above the legal limit.

5 Textiles for the protection of workers from risks to their health and safety; and membranes intended for use in medical textiles, filtration in water treatment, production processes and effluent treatment shall apply from 4 July 2023
6 https://www.oeko-tex.com/importedmedia/downloadfiles/STANDARD_100_by_OEKO-TEX_R__Limit_Values_and_Individual_Substances_According_to_Appendices_4__5_en.pdf
One fraction (wool/other fibres) out of 20 contained PFOA above the OEKO-TEX limit but none of them contained values above the legal limit. One cancerogenic arylamines (3,3-dimethoxybenzidine) were found in the shirt fraction made of cotton. But the value was not above either OEKO-TEX or the regulated limit value. All fractions were screened with XRF for elements and all findings were analysed further with ICP. One fraction made of wool contained values above the OEKO-TEX limit of Chromium. The others were not over legal restrictions or OEKO-TEX limits. Three fractions (swimwear PA, wind/workout jackets PES and wool/other fibers) contained chlorinated phenols above the OEKO-TEX limit values but none of them contained values above the legal limit.

It would be possible for OEKO-TEX to certify 15 out of 20 fractions. Polyamide swimwear, polyester functional jackets and one wool fraction failed due to high levels of chlorinated phenols. One wool fraction failed due to high levels of Chromium VI. Two wool fractions failed due to high levels of NPEO. One wool fraction also failed due to high levels of PFOA.

Detailed analytical results are found in the separate document *Classification and risk assessment - analytical results.*

### 8 Recommendations on how to use data in this guide

#### 8.1 Recommendations on chemical analyses of textiles for material recycling

As has been previously described, it is important to note that the analysis performed have been done irrespective of which recycling technology that is realistic from a material point of view. Performing analysis with mechanical recycling as the basis will provide the worst-case scenario and will give the most information possible about textile fractions for material recycling, thus, all analysis has been performed on material that has been mechanically processed. In Table 5 below, typical categories of materials are presented, describing the theoretical risk level, indicators for chemical content and the recommended analyses for quality assurance of the processed material. In addition, the table has been complemented with the recycling technology that is most likely for the given material category. It is important to note that mechanical recycling does not necessarily mean that the mechanically processed fiber will be used for production of a new product in the same category, or even within the same industry. The potential use of mechanically processed fiber will depend on many parameters where chemical content is only one; for example, mechanically processed fiber with a lower average fiber length distribution may not be a good raw material for producing a garment or a new textile, but would work well in a nonwoven product. In these cases, chemical legislation specific for these product categories apply. It is also important to note, that recycled fiber used for yarn spinning must, for technical reasons, be blended with virgin fiber yielding a recycled content in the final blend of 30-50%, in some cases somewhat higher for wool. This means of course, that any chemical content in the recycled fiber quality will be further reduced in the blend, under the presumption that the virgin material is chemically compliant.

**Table 7. Material categories, recommendation on analyses and recycling technology preferred**

<table>
<thead>
<tr>
<th>Material</th>
<th>Product types used and Chemical risk level (low, medium, high)</th>
<th>Indicators and Recommended analysis</th>
<th>Recyclign technology suitable based on material characteristics other than chemical content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Garment Type</td>
<td>Recycling Method</td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>-----------------------</td>
<td>---------------------------</td>
<td></td>
</tr>
<tr>
<td>Cotton (max 3% lycra)</td>
<td>T-shirts and hoodies - low</td>
<td>Mechanical recycling possible with low lycra content.</td>
<td></td>
</tr>
<tr>
<td>Polycotton</td>
<td>Workwear, trousers - high</td>
<td>Mechanical recycling unlikely – depolymerization methods</td>
<td></td>
</tr>
<tr>
<td>Acrylic</td>
<td>Fashion garments - low</td>
<td>Mechanical recycling possible but beneficial fiber length distribution required</td>
<td></td>
</tr>
<tr>
<td>Polyamide/lycra</td>
<td>Swimsuits - medium</td>
<td>Mechanical recycling not an option, depolymerization methods</td>
<td></td>
</tr>
<tr>
<td>Polyester</td>
<td>Outdoor jackets - high</td>
<td>Mechanical recycling not an option, depolymerization methods</td>
<td></td>
</tr>
<tr>
<td>Wool blends</td>
<td>Mixed knits - medium</td>
<td>Mechanical recycling possible</td>
<td></td>
</tr>
<tr>
<td>Other garments</td>
<td>Low</td>
<td>Mechanical recycling possible but beneficial fiber length distribution required</td>
<td></td>
</tr>
</tbody>
</table>

### Recommendations on sorting of textile materials

When giving recommendations on sorting of textile materials within this guide, it is important to note that these recommendations relate to textile for material recycling only. Items for reuse have a different sorting scheme which is based on parameters other than fiber type and material construction.

The recommendations on sorting for textile recycling take several parameters into consideration, these are:
- Fibre type
- Chemical content
• Material construction (having an impact on resulting fibre length distribution for mechanical processing)
• Available (now and in the future) recycling technologies and their limitations

In general, the routes for handling collected textile are several and can, for simplification, be divided into mechanical, thermomechanical and chemical methods according to Figure 3. As has been explained, mechanical recycling is to be considered as the case in which the importance of chemical content has the highest significance. This is due to the fact that these processes do not involve any separation or extraction steps. Figure 3 also visualises how mechanically processed textile can be used for several different application in different industry sectors, meaning that the requirements and legislation valid for the resulting product type is of great importance. As for depolymerisation processes, these are very specific with the aim of producing monomer for polymerisation. Therefore, these processes will enable purification of the material, removing unwanted substances during the recycling process. For dissolution of cellulose based materials, the situation is similar although these processes do not involve separating units in the polymer chain. For these processes it is more important to focus on the quality of the resulting product, including any chemical content, and substances in the feedstock that may disturb the efficiency of the recycling process itself.

![Figure 3. Recycling routes for textile materials](image-url)
Polyester
- workwear
  - depolymerisation
- Sportswear
  - depolymerisation
- Fashion garments
  - woven
  - knitted
  - depolymerisation
  - mechanical processing

Cotton
- >98% cotton
  - Pure cotton regeneration (by dissolution)
  - Woven (denim, bedlinen, shirts etc.)
  - Nonwoven applications
  - Fiber reinforcement in plastics
- <98% cotton
  - Knitted (sweatshirts, cardigans, underwear etc.)
  - Mechanical processing

Polycotton
- Woven (healthcare wear, workwear)
- Knitted (fashion items, healthcare)
- Separation based on depolymerisation
- Mechanical processing for non-textile applications
- Mechanical processing

Acrylic
- Pure Acrylic
  - Woven
  - Knitted
  - Mechanical processing
- Acrylic Blends
  - Woven
  - Knitted
  - Mechanical processing

Polyamide
- PA 6
  - Depolymerisation
- PA6,6
  - Depolymerisation
# Appendix 1 Legal restriction regarding CMR substances in textile materials

<table>
<thead>
<tr>
<th>Substance</th>
<th>Regulated limit (by weight)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% ppm</td>
<td></td>
</tr>
<tr>
<td>Chromium VI compounds</td>
<td>0.0001 1</td>
<td>extraction (expressed as Cr VI that can be extracted from the material)</td>
</tr>
<tr>
<td>Cadmium and its compounds</td>
<td>0.0001 1</td>
<td>extraction (expressed as Cd that can be extracted from the material)</td>
</tr>
<tr>
<td>Arsenic compounds</td>
<td>0.0001 1</td>
<td>extraction (expressed as As that can be extracted from the material)</td>
</tr>
<tr>
<td>Lead and its compounds</td>
<td>0.0001 1</td>
<td>extraction (expressed as Pb that can be extracted from the material)</td>
</tr>
<tr>
<td>Benzene</td>
<td>0.0005 5</td>
<td></td>
</tr>
<tr>
<td>Benz[a]anthracene</td>
<td>0.0001 1</td>
<td></td>
</tr>
<tr>
<td>Benz[e]acephenanthrylene</td>
<td>0.0001 1</td>
<td></td>
</tr>
<tr>
<td>benzo[a]pyrene; benzo[de]chrysene</td>
<td>0.0001 1</td>
<td></td>
</tr>
<tr>
<td>Benzo[e]pyrene</td>
<td>0.0001 1</td>
<td>Limit value per each PAH</td>
</tr>
<tr>
<td>Benzo[j]fluoranthene</td>
<td>0.0001 1</td>
<td></td>
</tr>
<tr>
<td>Benzo[k]fluoranthene</td>
<td>0.0001 1</td>
<td></td>
</tr>
<tr>
<td>Chrysene</td>
<td>0.0001 1</td>
<td></td>
</tr>
<tr>
<td>Dibenzo[a,h]anthracene</td>
<td>0.0001 1</td>
<td></td>
</tr>
<tr>
<td>α, α, α,4-tetrachlorotoluene; p-chlorobenzotrifluoride</td>
<td>0.0001 1</td>
<td></td>
</tr>
<tr>
<td>α, α, α-trichlorotoluene; benzotrichloride</td>
<td>0.0001 1</td>
<td></td>
</tr>
<tr>
<td>α-chlorotoluene; benzyl chloride</td>
<td>0.0001 1</td>
<td></td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>0.0075 75</td>
<td></td>
</tr>
<tr>
<td>1,2-benzenedicarboxylic acid; di-C 6-8-branched alkylesters, C 7-rich</td>
<td>0.1 (sum) 1000 (sum)</td>
<td></td>
</tr>
<tr>
<td>Bis(2-methoxyethyl) phthalate</td>
<td>0.003 30</td>
<td>50</td>
</tr>
<tr>
<td>Diisopentylphthalate</td>
<td>0.003 30</td>
<td>50</td>
</tr>
<tr>
<td>Di-n-pentyl phthalate (DPP)</td>
<td>0.003 30</td>
<td>50</td>
</tr>
<tr>
<td>Di-n-hexyl phthalate (DnHP)</td>
<td>0.003 30</td>
<td>50</td>
</tr>
<tr>
<td>N-methyl-2-pyrrolidone; 1-methyl-2-pyrrolidone (NMP)</td>
<td>0.3 3000</td>
<td></td>
</tr>
<tr>
<td>N,N-dimethylacetamide (DMAC)</td>
<td>0.3 3000</td>
<td></td>
</tr>
<tr>
<td>N,N-dimethylformamide; dimethyl formamide (DMF)</td>
<td>0.3 3000</td>
<td></td>
</tr>
<tr>
<td>1,4,5,8-tetraaminoanthraquinone; C.I. Disperse Blue 1</td>
<td>0.005 50</td>
<td></td>
</tr>
<tr>
<td>Benzenamine, 4,4’-(4-iminocyclohexa-2,5-dienylidenemethylene)dianiline hydrochloride; C.I. Basic Red 9</td>
<td>0.005 50</td>
<td></td>
</tr>
<tr>
<td>[4-(4,4’-bis(dimethylamino)benzhydrylidene)cyclohexa-2,5-dien-1-ylidene]dimethylammonium chloride; C.I. Basic Violet 3 with ≥ 0,1 % of Michler's ketone (EC no. 202-027-5)</td>
<td>0.005 50</td>
<td></td>
</tr>
<tr>
<td>4-chloro-o-toluidinium chloride</td>
<td>0.003 30</td>
<td></td>
</tr>
<tr>
<td>2-Naphthylammoniumacetate</td>
<td>0.003 30</td>
<td></td>
</tr>
<tr>
<td>Substance</td>
<td>Concentration</td>
<td>Time (min)</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------</td>
<td>---------------</td>
<td>------------</td>
</tr>
<tr>
<td>4-methoxy-(m)-phenylene diammonium sulphate; 2,4-diaminoanisole sulphate</td>
<td>0.003</td>
<td>30</td>
</tr>
<tr>
<td>2,4,5-trimethylaniline hydrochloride</td>
<td>0.003</td>
<td>30</td>
</tr>
<tr>
<td>Quinoline</td>
<td>0.005</td>
<td>50</td>
</tr>
</tbody>
</table>