CHALMERS

Estimation of Average Chemical Content in Textile Products

The case of polyester and polyamide

Master of Science Thesis in the Master Degree Programme of Environmental Measurements and Assessments

XUE WU

Division of Environmental Systems Analysis
Department of Energy and Environment
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2012

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Xue Wu
Göteborg, 2012

Abstract

Textile industry is a chemical intensive sector and nearly every step in the textile manufacturing requires multifarious chemicals. The large quantity of textile products around consumers and their chemical-rich characteristic have made textile chemicals a concern for researchers and authorities for long time.

This project deals with residual chemicals in textile products. The purpose of this project is to develop a method for estimation of the average chemical content in textile products in terms of the presence of specific chemical substances and their concentrations which are in the unit of weight percentage of the textile substrate. It is attempted to make a full mapping of residual chemicals in textile products other than just the chemicals regarded as dangerous traditionally. The successes of this project could further facilitate estimation of chemical stocks and emissions to the environment on a society level, and contribute to the management of chemicals in consumer products in Sweden.

The methodology of this project is based on systems analysis. Literature review is the main research method and two case studies on polyester and polyamide textile products are elaborated. The method developed to estimate average chemical content in textile products comprises of two phases—qualitative information acquisition and quantitative information acquisition. In the first phase, possible residual chemicals in textile products are identified. An initial qualitative chemicals list is constructed for the most common fibers. Fiber-specific chemicals lists are compiled and updated when doing case studies. Quantitative information acquisition is the process to quantify chemical concentrations. Three methods are utilized--extrapolate from *applied amount* and *degree of fixation* of chemicals in the manufacturing processes; utilize direct data collected from previous surveys; and substitute with detection limits as for the problematic substances.

In this study, 166 textile auxiliaries and 266 dyestuffs are identified as residual chemicals in finished textile products. Most of the chemicals come from coloring and functional finishing processes. The average chemical content in polyester textile products includes 88.5% polymer substrates, 2.3% fillers and impurities, 0.7% pretreatment agents, 6.5% dyestuffs and dyeing auxiliaries, and 2% functional finishing agents. For polyamide textile products, the average chemical content is 90.6% polymer substrates, 2% fillers and impurities, 0.7% pretreatment agents, 4.7% dyestuffs and dyeing auxiliaries, and 2% functional finishing agents. Generally the average concentration of each substance is estimated by dividing the concentration of the chemical group to the number of chemicals identified in that group. A lot of uncertainties lie in the estimation, but as an initiative attempt to calculate the average chemical content, the project provides a method which could be used for other consumer goods as well.

Keywords: Textile products, Residual chemicals, Average content, Polyester, Polyamide

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Abbreviations

ACS	American Chemical Society
BAT	Best Available Techniques
BHET	Bishydroxyethylter-ephthalate
BREF	BAT reference document
CAS number	Chemical Abstracts Service registration number
CiP	Chemical in Products
COD	Chemical Oxygen Demand
DEPA	Danish Environmental Protection Agency
ECHA	European Chemicals Agency
EPA	Environmental Protection Agency
ESD	Emission Scenario Document
EU	European Union
IPPC	Integrated Pollution Prevention and Control
IPR	Industrial Property Right
KemI	Swedish Chemicals Agency
MSDS	Material Safety Data Sheet
OECD	Organisation for Economic Co-operation and Development
PA	Polyamide
PAN	Polyacrylonitrile
PBT	Poly(butylene terephthalate)
PE	Polyethylene
PEC	Predicted Environmental Concentration
PES	Polyester
PET	Poly(ethylene terephthalate)
PNEC	Predicted No Effect Concentration
PP	Polypropylene
PTT	Polytrimethylene Terephthalate
PUR	Polyurethanes
PVC	Polyvinyl chloride
REACH	Registration, Evaluation, Authorisation and Restriction of Chemical substances
RSL	Restricted Substance List
SAICM	Strategic Approach to International Chemicals Management
SMEs	Small and Medium-Sized Enterprises
SVHC	Substances of Very High Concern
UNEP	United Nations Environment Program

1. Introduction

1.1 Background

Chemicals and textiles

Chemicals are now widely used in consumer goods. About 143,000 chemical substances were pre-registered under REACH directive between 1 June and 1 December 2008 (ECHA, n.d.). According to the Swedish research program Chemitecs, more than 100,000 chemical substances are in commercial uses (Westerdahl, et al., 2010).The increasingly more chemical substances in articles for daily use have drawn the attention of the world. These chemicals can cause adverse health and environmental effects, but obviously the risks of these chemicals are still unclear, and our knowledge regarding the chemicals in consumer goods needs to be improved further in order to have a better management of chemicals and to reduce the risks to the greatest extent.

Textile products are always around us in forms of apparel, furniture, bed linen, and so on. The production of the first type of synthetic fiber Nylon by the American company Du Pont in 1930s is a milestone of the polymer chemistry (Hedge, et., al., 2004) and since then synthetic fibers have been making the world of textile products even more varied and graceful.

Without any doubt, the textile industry is a chemical intensive sector. Pesticides and fertilizers are applied in the cultivation of cotton. Various chemicals are added as process chemicals or auxiliaries in order to make the manufacturing process easier or to obtain certain functions. Dyestuffs are used to achieve the desirable colors (KemI, 2011). The number of chemicals applied in textile manufacturing is difficult to define. According to Lacasse and Baumann, in the textile finishing processes (fabric pretreatment, dying, printing and functional finishing) as much as 2,500 chemicals are applied (Lacasse and Baumann, 2003, cited in OECD, 2004). Thanks to the various chemicals, people can wear colorful clothes and sleep in comfortable bed linen nowadays. However, as peoples' self-protection consciousness and environmental awareness enhance, attentions have been paid on chemicals contained in the finished textile products which come into frequent contact with consumers. Actually, textile industry is always of high environmental concern. Some textile chemicals may be very harmful to human health and the environment, and the studies on their risks are constantly carried out. In order to minimize the adverse effects from textile chemicals, it is of major importance to achieve a good management of textile chemicals.

Residual chemicals in finished textile products

There are various environmental issues related to textile industry, of which the most serious may be the discharged wastewater from textile industry and residual chemicals contained in textile products. Other important problems include energy consumption,

air pollution, and solid wastes disposal and so on (Lacasse and Baumann, 2004, p 484-646).

In this project the focus of environmental issues from textiles is the residual chemicals in textile products. A great number of media reports have aroused public concern on textile chemicals such as azo dyes in garments especially in baby clothes, formaldehyde for non-wrinkle treatment of bedding, and organic tin compounds in sports apparel and raincoats (Lacasse and Baumann, 2004, p 608). Some chemical substances in textile products are already found to be carcinogenic, thus their presence, regardless of the quantity, is considered to be a risk to human health (DEPA, 2003).

Early in 1995, a study by the Swedish Chemicals Agency (KemI) identified that 40-50% of the tested clothes contain unwanted substances which are harmful for the environment and human health (KemI, 1996, p12). The harmful substances can be exposed to people through three paths: (DEPA, 2003):

- Dermal exposure: exposure through direct contact with "free" chemicals in the textile products or degradation products of the textile chemicals;
- Ingestion exposure: exposure to children when they put the textile into mouth;
- Inhalation exposure: exposure of evaporated chemicals when breathing.

The residual chemicals in textile products could also been washed off during normal laundry and deteriorate the water environment if not effectively treated.

Chemical content information

With regard to residual chemicals, currently more attentions are paid to "harmful" or "toxic" substances. Governments and companies establish lists of unwanted chemicals in products. This kind of negative-content information exchanging method is very common in textile sector and can greatly benefit consumers and the environment. However, it has low reactive efficiency when new chemicals of concern emerge (UNEP, 2011). Moreover, among the various chemicals applied in consumer goods, only a small fraction of them have full data on their ecological effects (Nimkar and Bhajekar, n.d.). Therefore only information on the "harmful" substances is not adequate for a good management of chemicals.

A comprehensive mapping of chemicals in textile products could address the problem of negative-content information systems and has significant meaning in order to achieve a better management of textile chemicals. According to the United Nations Environment Program (UNEP, 2011) knowledge on the chemical content in textile products could support early action in chemical management. Chemical content information can be used by manufactures to improve product development, or by governments to estimate the stocks and emissions of chemicals in textile products, or by consumers as the basis of decision making when purchasing products, or by researchers to acquire reference information, etc.

The information systems of textiles right now are just on the level of fiber content by means of fiber content labels on finished textile products(UNEP, 2011), but the chemical content information is still difficult to know. Reasons for the lack of information include:

- More focuses on the functions of incorporated chemicals rather than on the exact molecular structures. Chemical composition of materials may be not fully known and the communication of chemical information is usually based on their functions such as flame retardant, water repellent, etc. (Tivander, et al., 2010).

- The chemical composition of materials and finished products are protected as industrial property rights (Tivander, et al., 2010). It is generally impossible to expect chemical or textile producers to release the full chemical content of their products because it may be associated with their market competitive power.

- Loss of information through the textile supply chain results in producers being unclear about the chemical composition of the complex materials they sourced from upstream producers (Zhang, 2009)

- The chemical composition of textile products may change as the technology progresses, legislation tightens and peoples' environmental awareness rises, e.g. emerging of new synthesized chemicals, restriction of highly toxic chemicals, etc.

The chemical content is greatly related to human health and environmental quality. Therefore more efforts are needed in order to make clear the chemical content of textile products.

1.2 Aim and objectives

The aim of this study is to develop a method for estimation of average chemical content in textile products. Case studies are conducted to test the method. The estimated average chemical content will allow further estimation of chemical stocks and emissions to the environment on a society level and ultimately contribute to a better management of textile chemicals.

Detailed objectives are as following:

- Collect information related to residual chemicals in finished textile products

- Develop a method to estimate the average chemical content in textile products in terms of existence of specific substances and their concentrations expressed as mass fraction of the textile product.

- Update the information and compile a qualitative datasheet of possible residual chemicals in textile products.

- Carry out two case studies of synthetic fibers to test this method and construct a quantitative datasheet for each textile material.

- Evaluate this method in terms of uncertainty and applicability for other consumer goods.

1.3 Methodology

Direct analysis is the most efficient way to clarify the residual chemicals in finished products, but it cannot give the average chemical content in textile products efficiently because laboratory testing would be impossible to analyze all the products in use and the overall chemical substances potentially contained in them. The analysis work would be too costly and slow. Moreover, there is no ideal about what to measure in laboratories and there are still no test methods for some textile chemicals (KemI, 1996, p17). Therefore, the methodology of this project is based on systems science in order to achieve a relatively comprehensive mapping of chemicals in textiles and to get a more general result which meets the aim of the project. Any other methods in nature sciences and technology are not feasible to solve such general problem within the available time and resources.

The research methods of this project include (Duignan, 2008):

- Search of scientific literatures: The selection of literature is focused mainly on those which have synthesized other research evidences, for example, reports which have been based on several laboratory tests and books which aim to provide comprehensive information related to the topic.

- Analysis of previous projects with similar aims: Publications from previous research usually integrate a mass of information and have further development on the topic. This method is a fast way to get the knowledge of the latest research findings.

- Analysis of documents and materials: This is to analyze other documents and materials such as organizational publications, legislations, industrial guides and so on. Relevant information is further collected and synthesized in order to get familiar with the textile industries and chemicals, and to allow the method development for estimation of average chemical content in textile products.

- Information evaluation: The information collected needs to be evaluated on their reliability and timeliness.

- Data analysis: Data is summarized from trustable publications, analyzed and compiled into datasheets, including both qualitative and quantitative datasheets.

- Case study: Case studies are conducted to test the method developed and to demonstrate the usage of the method in estimation average chemical content in

textiles.

1.4 Delimitations

- Textile products

The focus of this study is textiles because there are large areas of textile products in society which may result in high amount of emitted chemicals. Moreover, the normal laundry of textile products further enhances the emission of chemicals to the environment. The research priority of this study is given to clothing and household textiles because of their frequent contacts with consumers. Technical textiles such as industrial filters, geotextiles and textile for automotive use are excluded in this project because the specific functions of these textiles require specific chemicals, which means they should be analyzed specifically. Textile accessories such as buttons and zippers are also excluded since they are not made of textile fibers.

Another clarification is that the focal point is textile products before consumer use, rather than textile products which have been used and washed in daily laundry. During consumer use the average chemical content in textile products will change gradually, but this problem is not within the scope of this project.

- Materials

This study has an emphasis on synthetic fibers which are made from petroleum chemicals originally. Synthetic fibers are now used massively in textile industry and they are generally regarded as less environmental friendly since they are made from nonrenewable resources. Two case studies are carried out for textile products made of polyester and polyamide which are the two most common synthetic fibers.

- Chemicals

The chemical substances of concern in this study include textile auxiliaries, processing chemicals and dyestuffs. The polymer substrate is assigned an average mass fraction in the final results. The study does not only focus on the substances which are regarded harmful traditionally, but also the other substances. The study endeavors to make a relatively comprehensive mapping of the residual chemicals in finished textile products.

- Average content

Due to the large amount of textile products in use and the wide range of chemicals applied in the textile manufacturing processes, it is impossible to get the chemical content of each individual textile product at present. However, there are possibilities to estimate the average chemical contents in textile products on a higher aggregated level. The average chemical content is the mean chemical composition on a general level. It is a statistical construct rather than real ingredient of a specific textile article. The sum of the average chemical content for a product category should be equal to 100%.

- Geographical boundary

For textile products, the geographical boundary is not easy to define because the textile industry is one of the most globalized sectors. It is common that different production steps are conducted in different locations. According to the Swedish Chemicals Agency (KemI, 2011), only a small share of textiles are manufactured in Sweden, while the most of them are imported from developing countries such as Bangladesh, India and China. This fact further makes it difficult to define the geographical boundaries. However, Sweden has high concern about the textile chemicals and relatively sound information systems compared to other countries. So, according to the available resources, Sweden is selected as the study area and the focal point is the textile products on the Swedish market.

- Time horizon

The study is a retrospective one and the results are valid for textile products from the year of 2003 due to the references used in this project.

1.5 Structure of the report

Chapter two reviews the previous research which has similar aims as this project in order to have a quick overview of the status of research in this field. Chapter three goes deep into the fundamental information about textiles. This is an essential part in order to gain the ability to collect and evaluate relevant information. In chapter four, information sources related to textile chemicals are investigated further and potentially useful data sources are introduced as well. Chapter five is the part to develop a detailed method so that the aim of this report could be achieved step by step. In chapter six and seven, case studies of polyester and polyamide textile products are carried out with the method developed. Chapter eight discusses the uncertainties of the results and applicability of the method for other consumer goods. Finally chapter nine makes a conclusion of this study.

2. Relevant previous research activities

Previous research on residual chemicals in textile products is limited, possibly because residual chemicals in textiles are usually not considered as having very harmful impacts on human health and the environment. There are some projects related to chemicals in products on a general basis which include textile as a product category. Five most relevant projects are introduced below.

2.1 Chemicals in Textiles project by KemI in 1996

As early as in 1996, the Swedish Chemicals Agency (KemI) conducted a survey on chemicals remaining in textile products on commission of the Swedish Government, aiming at reducing human and ecological risks from textile chemicals. Experts from textile industries and authorities were involved in this project. Since most textile products in Sweden are imported from Asian producers, the report had a focus on chemicals used by Chinese and Indian textile manufacturers. The Swedish textile importation trade statistics were analyzed, and so as the structure of textile market. In-depth studies were carried out for the textile manufacturing processes and chemicals. The residual chemicals in textile products were identified and their risks to human health and the environment were assessed. The method used to identify the remaining chemicals was through studies of the manufacturing processes and chemical and physical properties of the chemical substances. It was concluded that some hazardous chemicals are present in finished textile products, but in risk assessment, uncertainties exist both in knowledge on the effects and concentrations of residual chemicals (KemI, 1996). This project was a very early attempt in mapping of chemicals in textile products and a quite thorough investigation of the Swedish textile market. The project report was cited in many subsequent publications.

A Textile Chemicals List was provided in the project report. The list of possible residual chemicals in textile was compiled through consultations with experienced specialists who deliberately focused on textile manufacturing in areas where the most textile products on Swedish markets are exported from. Based on three consulting reports, a list containing around 300 substances (except dyestuffs) was compiled. It was cut down to about 200 through considering of chemical and physical properties of the chemical substances and assuming chemicals applied on early steps of textile production do not remain in the final products. Chemicals on the list were classified according to their application points and functions. With regard to the concentration of chemicals in textile products, the project report also provided typical ranges of a few chemical groups, for example, the typical concentration of dyes was between 0.05% and 3% in the finished textile products according to the report (KemI, 1996).

This project report is very useful for the thesis project because it provided abundant information on textile industry, exclusively focused on Swedish textile market, and has similar delimitation of textile products with the thesis project. The Textile Chemicals

List in this report serves as a basis for the qualitative datasheet of this project. But the report just identified the possible residual chemical substances rather than indicating the concentration of each substance. The list may not comprehensively cover all the possibly existing substances. The report was published 16 years ago, and changes may have happened as legislation tightens and techniques progresses.

2.2 Mapping of Chemical Substances project by KemI in 2008

In 2008, a project was carried out in KemI on Mapping of Chemical Substances in Three Types of Material: plastics, rubbers and textiles, aiming to identify chemicals in these three categories of materials through literature studies. An Excel file was constructed containing subject names, trade names and CAS numbers of chemical substances and in what materials they occur. The chemicals were categorized by their functions, such as anti-wrinkle agents, flame retardants etc. For some chemicals, information on their concentration was included in the datasheets. The result of this project was incorporated in the database Commodity Guide which is introduced in Chapter 4 (KemI, 2008).

The main method of this project was literature review and with regarding to the textile part, the main reference was the 1996 Chemicals in Textile report by KemI. Besides compiling the data in an Excel file, another main contribution of this report was that the chemical substances were separated for each type of textile materials. Textile fibers covered included cotton, polyacrylic, polyamide, polyester, silk, wool, and viscose. The datasheet also excluded some chemicals listed in the 1996 Chemicals in Textiles report in case they were provided without CAS numbers. The concentration information was also referred from the 1996 report. It is worth mentioning that the author assigned each substance with the concentration which represents the whole chemical group. For example, each of the 236 dyestuffs for polyester fiber was assigned a concentration of 0.05%-3%. If this data is used as the average chemical content it would lead to overestimation of the chemical amounts.

2.3 Chemicals in Products project by Kogg and Thidell in 2010

This project aimed to provide an overview of relevant information systems with regard to Chemicals in Products (CiP) and analyzed the needs of such CiP information of different stakeholders. The method to identify systems providing CiP information was through literature review and interview with associated stakeholders (Kogg and Thidell, 2010).

The identified CiP information systems most relevant for textile sectors include:

- Joint Article Management Promotion Consortium: a Japanese information system for downstream producers aiming to transfer chemical information through the supply chain.

- ÖKO-TEX: an international wide-spread voluntary labeling system for textile

products which has standard to evaluate the environmental performance of textile producers and products.

- Chemicall: database compiled by Swerea/IVF containing information on textile chemicals and materials, test methods, substitutions, and restrictions. It is only open for members.

- Restricted substance list (RSL): list of restricted chemical substances which the company does not want to have in their products.

CiP information systems are more developed in some sectors such as automotive and electronic industries. Chemical companies are legally required to report the chemical content of their products according to REACH regulation in European countries, but break of information chain is observed on sectors such as textile and furniture. It was concluded that there is growing demand of CiP information for stakeholders and gaps exist between the needs and available systems providing CiP information (Kogg and Thidell, 2010).

Although this project report did not dig into the chemical content of products, it provided knowledge on the types of information systems which can be useful for this thesis project. It contributes as a basis of data collection.

2.4 Chemicals in Products program by UNEP in 2011

Chemicals in Products (CiP) program is led by UNEP from 2009 in order to provide more information and knowledge to support the Strategic Approach to International Chemicals Management (SAICM) which has the goal "that by 2020 chemicals are used and produced in ways that minimize significant adverse effects on human health and the environment". Textile is within the scope of CiP program and a textile case study report was released in January 2011.This report evaluated the current information systems related to chemicals in textile products (UNEP, 2011). It is a more comprehensive overview of the information systems, and needs and gaps of information.

It concluded that for textile products, currently there is only an information system in place for the fiber content rather than CiP information systems. Product safety is the main driving force for the needs of CiP information by different stakeholders. There are initiatives in the textile sectors to disclose material content and chemical content of textile products but it's still impossible to get CiP information of the whole sector. Compared to CiP information systems, more frequently adapted are negative content information systems which declare undesired chemicals. Examples of such negative content information systems include RSLs and Ecolabels. This kind of negative chemical control may be lagging in efficiency when new chemicals of concern emerge, while a CiP information system can facilitate early reaction (UNEP, 2011).

This project further summarized the relevant information systems which can be helpful for the thesis project, and once again confirmed the difficulties in gathering CiP information of textile products at current situation.

2.5 Chemitecs program from 2009 to 2012

The program Chemitecs (Organic Chemicals Emitted from Technosphere Articles) is supported by the Swedish EPA, aiming to achieve a better understanding of emissions of chemical substances from daily use articles and to clarify the magnitude of this problem in Sweden with a focus on organic substances. Figure 1 provides an overview of the Chemitecs concept model. The environmental problem of chemicals emitted from the technical system to the nature system follows a cause-effect chain relationship. A product category contains many products; a product is consisted of different components; a component may have several different materials and a single material is consisted of many chemical substances. The emission of chemicals from the consumer products is related to the use phase, both the use type and the use environment. The average chemical content in products is essential information for estimation of emissions of chemical from consumer products (Tivander J., et al., 2010). There are several case studies conducted within this program, such as a national inventory of emissions of additives from plastic materials (Westerdahl, et al., 2010) and emissions from car tires (Einarson, 2009).

This program has a focus on organic compounds while the thesis project aims to provide a comprehensive overview of the chemicals. The thesis project could benefit the program in some way as it will investigate the average chemical content in a commonly used product category- textiles. The models used in Chemitecs program to calculate emissions could also be used for textile products after achieving the average chemical content, so that emission of chemicals from textile products can be estimated and chemicals can be better managed.

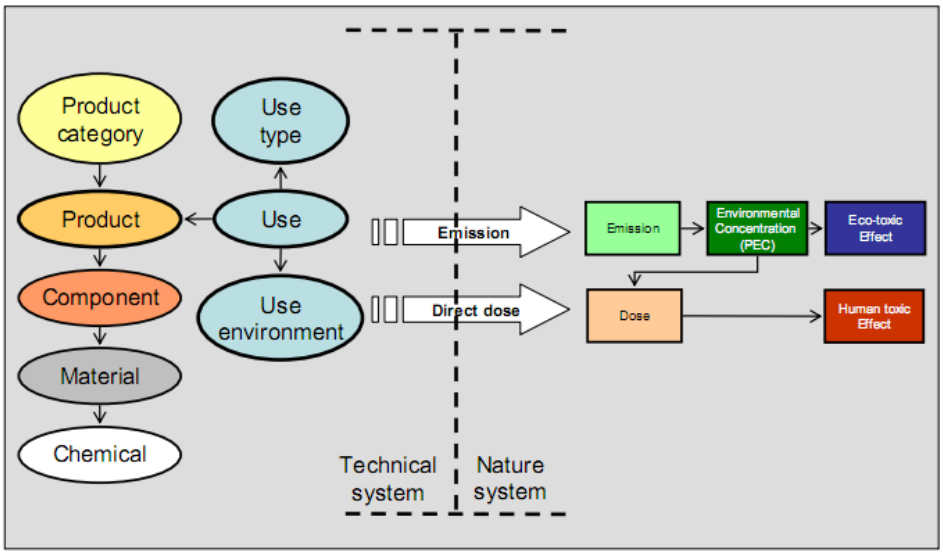

Figure 1. The overview of Chemitecs concept model (Tivander J., et al., 2010)

3. Fundamental information

3.1 Textile products

Figure 2 shows a simple classification of textile products. According to Integrated Pollution Prevention and Control (IPPC, 2003), among all the textile products in Europe, the volume of clothing textile accounts for 45%, followed by household textiles (20%), technical textiles (18%), interior textiles (10%), and other textiles (7%).

Although fibers could be thought of as the raw material for fabrics, and fabrics as that of finished products, in a broad sense they are all textile products. Usually consumers come into contact with finished products. However the assembling of fabrics into clothing or bedlinen is mainly physical processes, while the production of fibers and intermediate products requires a lot of chemicals.

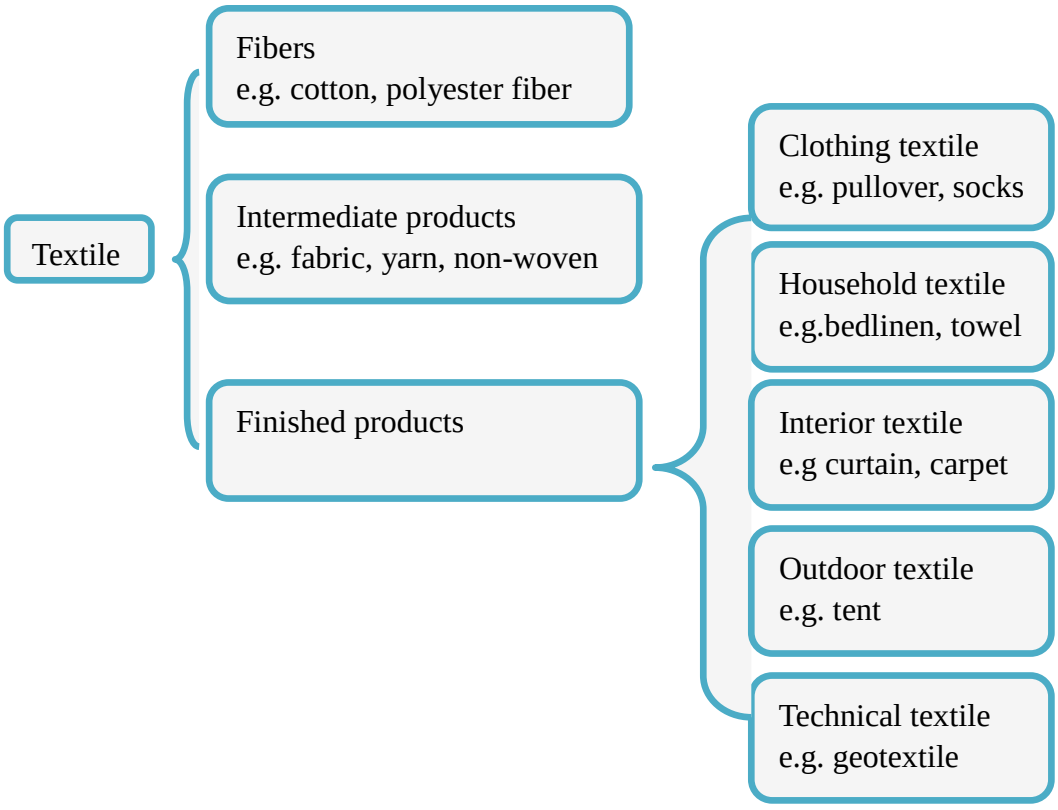

Figure 2.Classification of textile products (Created according to KemI, 1996)

3.2 Textile fibers

As demonstrated in Figure 3, fibers used in textile industry include both natural fibers and man-made fibers.

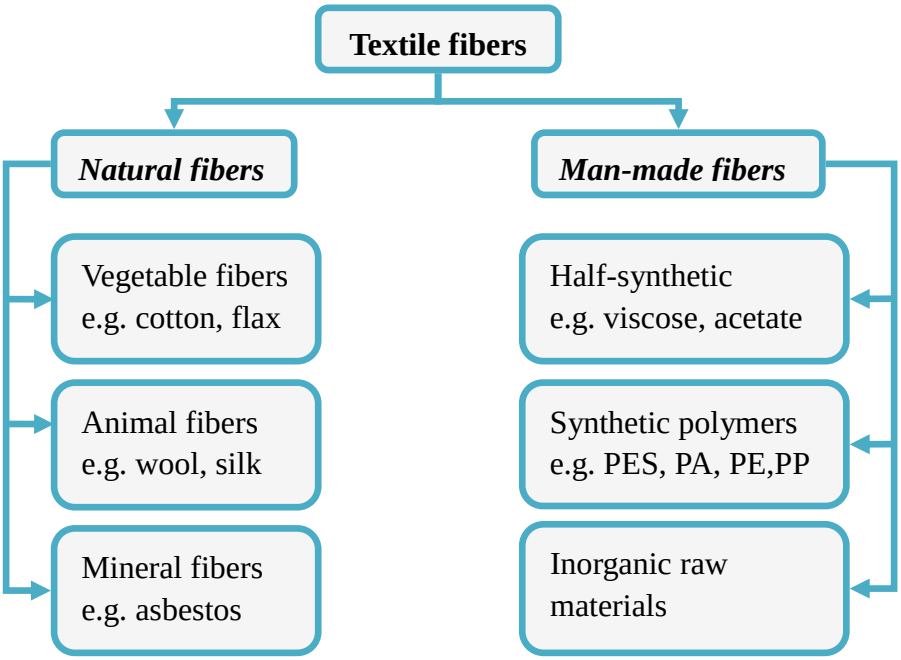

Figure 3. Textile fibers (Adjusted from OECD, 2004)

Natural fibers could be made from plants, animal products as well as minerals. Cotton and wool are the most common natural fibers for textile products. They respectively accounts for 38% and 3% of the total share of textile fibers in the year of 2001 globally (OECD, 2004, p13-14).

Man-made fibers which make the world of textile more varied and graceful are even more diverse. According to OECD (2004, p14), man-made fibers are classified into three groups-- half-synthetic fibers, synthetic polymers (also called synthetic fibers.), and fibers made from inorganic raw materials. Generally half-synthetic fibers are generated from chemical treatment of naturally occurring polymers, and synthetic polymers are made from petroleum originally (KemI, 1996, p30).

According to OECD (2004, p13-14), the most significant man-made fibers are polyester (PES), polyamide (PA), polyacrylonitrile (PAN), polypropylene (PP), regenerated cellulose and acetate. An estimation of relative importance of individual fibers, both natural and man-made, is provided by Lacasse and Baumann (2004), showing that PES accounts for 25%, which is the most important fibers, PA and PP account for 12% respectively. Synthetic fibers are playing an irreplaceable role in textile industry nowadays.

Compared to natural fibers, synthetic fibers, such as the widely used PES and PA, are generally considered to be more environmental harmful because they are originally generated from petroleum which is a nonrenewable resource, and they are not biodegradable essentially (Chen and Burns, 2006). Therefore, the research focuses on synthetic fibers because of their large quantity and undesirable environmental impacts.

3.3 Textile manufacturing

3.3.1 Main processes

Figure 4 shows the typical textile production chain (adjusted from IPPC, 2003, p15; Lacasse and Baumann, 2004, p75). The various textile manufacturing steps can be divided into two phases: upstream processes and finishing processes as indicated in figure 4. In upstream processes, natural fibers are cultivated and prepared for textile use; polymers produced from petroleum are manufactured into man-made fibers. The ready-made fibers go through processes such as spinning and texturizing to be made into yarns. Then fabric production process converts yarns (or sometimes fibers) into fabrics through technologies such as weaving and knitting (OECD, 2004, p16). The finishing processes, including pretreatment, dyeing, printing, and functional finishing and so on, are not in a sequent order with other steps but may be applied on fibers, yarns, or fabrics (IPPC, 2003, p15). Then textile products could be made-up through cutting, sewing and assembling of fabrics (OECD, 2004, p16).

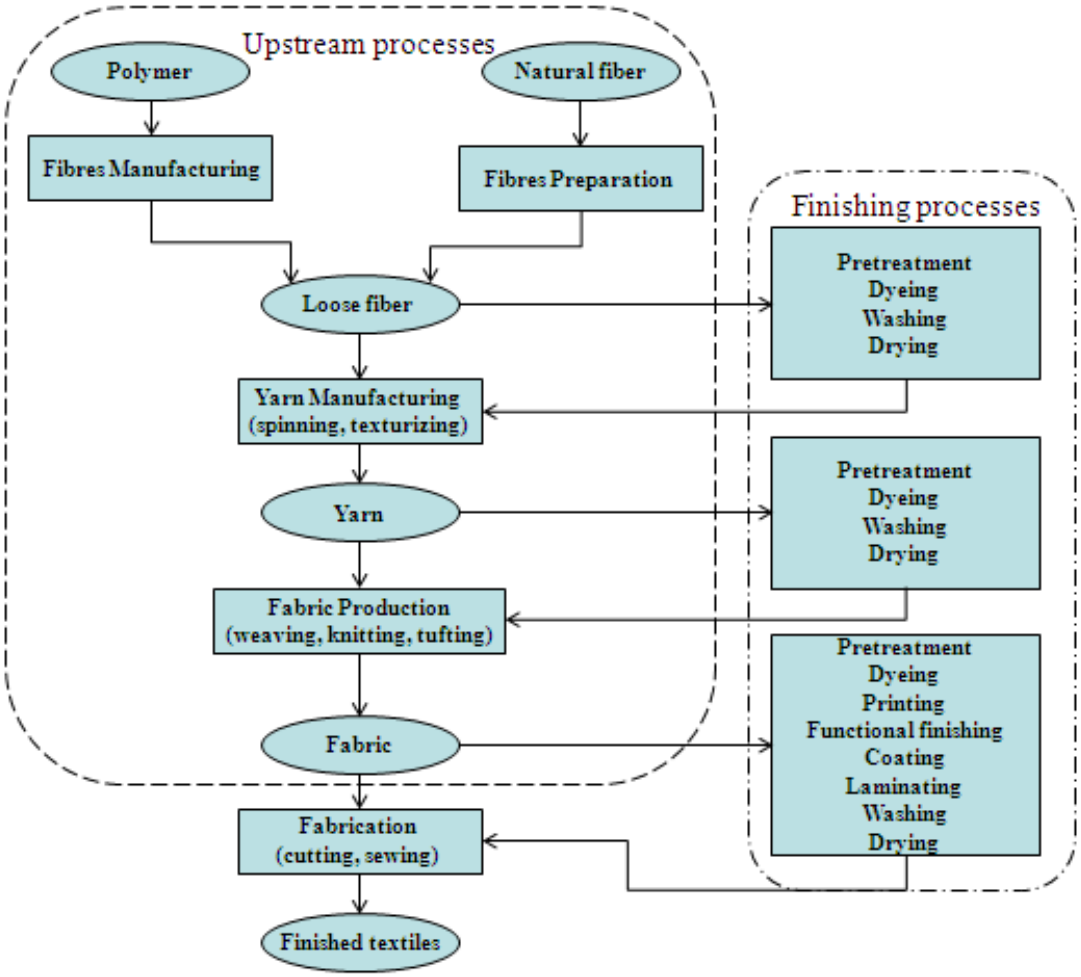

Figure 4.Typical processes in the textile industry (Adjusted from IPPC, 2003, p15; Lacasse and Baumann, 2004, p75)

To clarify, finishing processes should be differentiated from functional finishing. Textile finishing is a set of processes that impart textile colors and specific properties, including pretreatment, dyeing, printing and functional finishing, while functional finishing is flame-retardant treatment, anti-wrinkle treatment, water and soil repellent treatment and so on (KemI, 1996).

Due to the different properties of different fibers, the manufacturing processes and the points when chemicals are applied are different. Table 1 shows the textile processes and chemical processes for the most common fibers. The marker “X” represents which processes are subjected to which fiber materials. The details of the processes will be discussed below.

Table 1.The textile processes and chemical processes for different textile materials (Adjusted from KemI, 1996, p33)

Cotton	Synthetic	Silk	Wool	Textile processes	Chemical processes
UPSTREAM PROCESSES					
X	X X	X	X	Spinning Twisting	Addition of spinning oil Washing-out
X	X	X	X	Weaving, knitting	Sizing, Needle oil Washing-out
FINISHING PROCESSES					
Pretreatment					
X X	- X	X X	X -	Bleaching Brightening	Bleaching chemical treatment Washing out Addition of optical brightener
X	-	-	-	Mercerization	Alkali treatment Washing out
Coloring					
X X X	X X X	X X X	X - -	Dyeing Dye printing Pigment printing	Dissolution or reduction of dye, Precipitation Fixation Aftertreatment Washing-out Printing dye application Fixation Washing-out (not for pigment printing)
Functional finishing					
X X	X -	X -	- X	Winkle-resistant Shrinkage-resistant	Resin treatment (catalysis) Addition of softener, certain cases
X X	X -	- -	X X	Antistatic treatment Softening	Addition of antistatic agent and/or softeners
X	X	X	-	Water, oil, dirt repellent	Addition of polymers or hydrophobic substances
X	X	-	X	Flame retardance	Addition of flame retardants
X	-	X	X	Antimicrobial	Addition of pesticides

3.3.2 Upstream processes

Upstream processes cover processes from polymer manufacturing, fiber production, yarn manufacturing to fabric formation.

The production of natural fibers is the growing of cotton or breeding of animals while the production of man-made fibers is the chemical treatment of natural polymers or the generation of fibers from petroleum chemicals. As early as in the fiber production steps, chemicals are applied in terms of e.g. pesticides and fertilizers for cotton, and additives in the synthetic fibers (KemI, 1996, p30).

Yarn manufacturing is the turning of loose fibers into long and interlocked fibers in spinning mills (OECD, 2004, p17). Spinning technology is used both in synthetic and half-synthetic fiber manufacturing and yarn manufacturing. In the first process, polymer granulates, such as polyamide and polyester, are pressed through a fine nozzle to transform into filaments. In the second process, the fibers are outstretched, twisted and made into yarn. (KemI, 1996, p31) Spinning oils which may be mineral oil or ester oil are applied in order to reduce the friction and make the manufacturing work more smoothly. Some additives such as surfactants are also added into the preparation agents so that the spinning oil could be removed easily after fabric formation (KemI, 1996, p31).

Fabric formation uses technologies such as weaving and knitting to interlace yarns and to turn yarns into fabrics. Some fabrics which are called non-wovens are made of fibers directly (OECD, 2004, p17). The weaving or knitting processes apply great forces to the yarn, therefore some sizing agent or lubricant need to be used to prevent breakage of the thread. Generally these preparation agents are washed out in the following washing steps (KemI, 1996, p31).

3.3.3 Pretreatment

Pretreatment is the removal of impurities or by-products of textile materials in order to make them easy to dye or treat in the subsequent processes. Many chemicals are used in pretreatment. Therefore, pretreatment of textiles could be of high environmental concern due to the emission from textile finishing plants (OECD, 2004, p21).

Bleaching and brightening are common processes in the pretreatment of textiles. The difference is that bleaching is to remove the original yellowish impurities from the textile material and brightening is to apply optical brighteners to increase whiteness. Bleaching is usually not applied on pure synthetic fibers while brightening is not applied to wool (KemI, 1996, 31). However in some literatures, bleaching and brightening are not distinguished (Lacasse and Baumann, 2004; OECD, 2004). The following Table 2 shows possible optical brighteners for each type of fiber (KemI, 1996,

p32). The optical brighteners for cotton and viscose fibers are easily washed off and need to be renewed by using detergent, but they have good affinity to synthetic fibers because they are added during the fiber manufacturing (KemI, 1996, p32).

Table 2. Optical brighteners for different textile fibers (KemI, 1996, p32)

Substance	**Cotton/ Viscose**	**Wool/ Silk**	**Polyester**	**Polyamide**	**Polyacrylic**
Stibene disulphonic acid	X	X		X	
Distyryl biphenyls	X	X		X	
Coumarins			X	X	X
Benzoxazoles			X	X	
Benzimidazoles			X		X
Pyrazolines				X	X

Mercerization is another common process in pre-treatment with the purpose to increase fiber strength, luster and affinity to dyestuffs. Mercerization is usually applied for cotton and the chemicals used may be strong alkali such as sodium hydroxide, but the mercerization agents are usually washed out in the subsequent processes (KemI, 1996, p32).

3.3.4 Dyeing/Printing

Dyeing and printing are the processes to impart textile products the desired colors. They can be applied on fibers, yarns, or fabrics. Many physical and chemical mechanisms contribute to the coloring process, including ionic bond, covalent bond, hydrogen bond, electrostatic force and adsorption (OECD, 2004, p24).

Dyeing

Dyeing is a method of coloring in which dyestuffs are applied uniformly on textile material. In dyeing processes, commercial dyestuff formulations which contain dyestuffs, auxiliaries, and processing chemicals are dissolved or dispersed in dye liquor. Then textile substrate is dipped in the dye liquor and the dyes will migrate to the surface or interior fibrous structure of the textile substrate (Lacasse and Baumann, 2004, p159).

There are mainly two modes of dyestuff application onto textile materials as shown below (OECD, 2004, p24). The mode of dyestuff application influences the required amount of dyestuffs and their affinity.

- Exhaustion: Textile material is dipped into the solution of dyestuff and necessary auxiliaries and gradually colored through circulation of dyestuff bath or movement of textile material.

- Padding: Textile material is dipped shortly into a concentrated dyestuff bath and then pass through a squeezing unit to let dyestuff penetrates into the textile material and get rid of the surplus dyestuff.

Basically dyeing technologies can be classified as the following three types: (OECD, 2004, p24; Lacasse and Baumann, 2004, p162)

- Discontinuous (batch/exhaust) technology: A certain volume of textile material is dipped in the dye liquor and stayed for a period to allow disperse of dyes onto the textile material. The used bath liquor is drained off at the end and the textile material is washed with water to remove the unfixed dyestuffs. Exhaustion mode is the most commonly used method of dyestuff application in discontinuous technology.

- Continuous technology: Textile materials pass continuously through the padding mangle with dyestuffs applied. Fixation of dyestuffs on the textile material is by means of chemical, and thermo treatment. Washing is also needed to remove surplus dyes. Padding mode is the most commonly used method of dyestuff application in continuous technology.

- Semi-continuous technology: Similar to continuous technology but the fixation and washing are conducted discontinuously.

Printing

Printing is another method of coloring of textile substrate in which only specific areas of fabrics are colored so as to create desired patterns. The chemical and physical mechanisms happened between the dye and the textile material is similar to dyeing although printing uses different machines and technologies (Lacasse and Baumann, 2004, p213).

There are mainly three methods of printing as listed below: (OECD, 2004, p 25)

- Printing with dyestuffs: Dyestuffs are dissolved in small amount of water and thickening agents are applied to increase viscosity. Following the printing process are drying, fixation and washing. The types of dyestuffs used in printing are the same as in dyeing, but the concentration applied is higher.

- Printing with pigments: The most frequently used (around 50%) textile printing technology. Pigments are used together with binder and fixation agents to increase affinity, and also emulsifier, thickening agent, and softening agent. Washing step may be omitted after printing, drying and fixation. More chemicals will remain compared to printing with dyestuffs.

- Transfer printing: Print the pattern on paper, stick the printed paper on fabric and then the desired pattern is transferred to the fabric and paper is discarded.

Dyestuffs

Dyestuffs are used both in dyeing and printing processes. It is estimated that around 200 to 300 types of dyestuffs are utilized in textile finishing plants annually (OECD, 2004, p43).

Dyestuffs are usually classified according to their application class in industry. The classification of dyestuffs and their applicability to certain textile fiber are demonstrated in Table 3 (Lacasse and Baumann, 2004, p268; KemI, 1996, p34). A more detailed description of the various dyestuff classes are provided in Appendix 1.

Table 3. Dye type and applicability on different textile fibers (KemI, 1996, p34)

Dyestuff class	**Cotton Viscose**	**Silk**	**Wool**	**PES**	**PA**	**Acylic**
Acid dyes		**X**	**X**		**X**	
Basic dyes					**X**	**X**
Direct dyes	**X**	**X**	**X**		**X**	
Disperse dyes				**X**	**X**	**X**
Metal-complex dyes		**X**	**X**		**X**	
Mordant dyes		**X**	**X**			
Azoic dyes	**X**			**X**	**X**	
Reactive dyes	**X**	**X**	**X**		**X**	
Sulphur dyes	**X**	**X**				
Vat dyes	**X**					

The most frequently used dyestuffs are directive, reactive and disperse dyes (KemI, 1996, p35). Disperse dyes are commonly used for synthetic fibers, mainly for PES and PA. Carriers are usually needed to help the disperse dyes to penetrate the textile fibers (KemI, 1996, p36). Formally there are cases of skin allergens caused by disperse dyes but nowadays allergenic dyestuffs have been avoided in manufacturing (KemI, 1996, p41). Azo dyes accounts for 60%~70% of the dyes in current use. Some azo dyes may cleave into carcinogenic amines under reductive conditions, which is very harmful for human health. (Lacasse and Baumann, 2004, p554; Hübner, 1997, cited in OECD 2004, p33). It is worth mentioning that "azo dyes" is not the same as "azoic dyes". The latter is an application class while the former is a characterization based on chemical identity.

3.3.5 Functional finishing

Functional finishing is the treatment to gain certain special functions such as wrinkle resistance, water repellent, soil repellent, and fire retardant and so on. Functional finishing includes both chemical and mechanical treatments, but the focus here is the chemical finishing. The application of finishing auxiliaries is mainly by padding technology. Usually the padding liquor is multifunctional and several finishing

auxiliaries are used together. The chemical finishing is followed by drying and fixation (OECD, 2004, p25). Some details of the most common finishing processes will be discussed below.

Shrinkage-resistant and winkle-resistant finishing

This type of treatment is to increase dimension stability or the ability to recover after folding. Reactive resins and catalysts are used to treat the textile material, especially cotton, but the needs for this type of treatment of synthetic fibers are generally low. The most common chemicals used are various carbamate resins, urea formaldehyde, melamin formaldehyde, and dimethylol ethylene urea (KemI, 1996, p38).

Softening and antistatic finishing

This type of finishing aims to improve the handle of textile materials and to prevent stiffness resulting from shrinkage-resistant and winkle-resistant treatment. Softening agents such as sulphonated oils, waxes, paraffins, silicones or cationic quaternary ammonium compounds will remain in the finished products but will be washed out in normal laundry processes. Antistatic agents are usually used for synthetic textile fibers to avoid accumulation of electrostatic charges. Some antistatic agents could generate a conductible film on the textile surface, and they are durable for washing. Softeners and antistatic agents will be renewed by adding textile softeners after laundry (KemI, 1996, p38; Lacasse and Baumann, 2004, p443).

Water, oil, and dirt repellent finishing

This is to improve the repellence of the textile fabrics to water, oil and dirt through impregnating the textiles with repellent agents. This treatment is applicable for all types of textile fiber materials. Common chemicals include waxes, paraffins, fatty acid salts, silicones, polyvinyl chloride (PVC), polyurethanes (PUR), and fluorocarbons and so on (KemI, 1996, p39).

Flame-retardant finishing

For the product safety in daily use and in workplace, many products are flame retardant treated. The most commonly used flame retardant agents include organobromine or organoclorine compounds, boron or phosphorus compounds, and a variety of metal salts (KemI, 1996, p38). Flame retardants are coated on fibers instead of bound to it, so they are easy to be washed off (KemI, 1996, p100).

Antimicrobial finishing

Antimicrobial finishing is to prevent contamination by bacteria and insects to the textile products during storing. It is achieved by incorporation of biocides. The need of antimicrobial finishing for nature fibers is greater than that of synthetic fibers. Textile products for outdoor use and carpets are particularly in need of antimicrobial treatment (Lacasse and Baumann, 2004, p447). Antibacterial agents are recommended not to be used in textiles and clothing products by the Textile Importers' Association of Sweden (Textilimportörerna, 2003, p14). It is estimated that less than 5% of textile products for

consumer use are treated with biocides. (OECD, 2004, p31)

3.4 Textile chemicals

3.4.1 Classification of textile chemicals

A large amount of chemicals are used in the manufacturing of textile products. These chemicals can be categorized as following (Lacasse and Baumann, 2004, p81):

- Chemical fibers: the textile substrates, both natural and man-made fibers.

- Dyestuffs: Preparations for imparting colors on the textile products.

- Textile auxiliaries: chemicals which assist the processing of textiles. Ideally auxiliaries are washed out after fulfilling their tasks so as not to disturb the following processes, but some of them have been found remain on the finished textiles, for example, heavy metals from dyeing, and solvents from printing (KemI, 1996, p17).

- Processing chemicals: basic chemicals, e.g. acids, bases, and salts

3.4.2 Remaining chemicals

As evident from the above mentioned manufacturing processes, there are a large amount of chemicals used in textile production and finishing. However, not all the applied chemicals will end up in finished textile products. According to Lacasse and Baumann (2004, p608-609) the residual ratio of the chemicals depends on the properties of the chemical substances, the properties of the materials, the application conditions (liquor ratio, temperature, pH), and the amount washed off in washing steps.

A set of criteria was established in the CiP report by KemI (1996, p43) to sort out chemicals which may not remain in the completed textile products based on their specific characteristics and the way they are applied in the manufacturing processes. The list is as following (KemI, 1996, p43):

- Highly watersoluble substances are removed in the washing steps.
- Volatile substances whose boiling point is less than 100℃ evaporate in the treatments up to finished textiles.
- Auxiliary chemicals are removed after fulfilling their functions in the manufacturing processes.
- Certain process chemicals are consumed in production or degrade during use. Examples are bleaching agents and certain oxidation or reduction agents.

According to the above criteria, most surfactants (detergents, emulsifiers) and other watersoluble substances such as inorganic salts, alkalis, and acid would be washed out in wet processing. However, exceptions do exist, such as auxiliaries in print pastes which would not be washed out and most of them remain in the finished products. Provided the washing step is not effective, some hydrophilic chemicals may also remain (KemI, 1996, p43-44).

Usually most textile auxiliaries and processing chemicals applied in fabric preparation are consumed or washed away (Lacasse and Baumann, 2004, p608). Most of the chemicals added in the pretreatment process are also easily washed out except for those intended to remain, such as optical brighteners which may have a high rate of residue in finished textile products. (KemI, 1996, p33).Relatively more chemicals used in coloring and functional finishing processes will remain in the finished products (Lacasse and Baumann, 2004, p608). After dyeing and printing, most dyestuffs will remain in the finished textile products. Some chemicals used in after-treatment will also remain (KemI, 1996, p37). Most chemical finishes applied in functional finishing are also intended to remain.

4. Textile chemical related information sources

4.1 Legislation

Some European Union (EU) directives for environmental protection have direct impacts on the European textile industries (European commission, 2010). Regarding textile chemicals, two EU directives are the most relevant. They are introduced below.

Integrated Pollution Prevention and Control (IPPC)

The IPPC directive (Directive 2008/1/EC) requires "industrial and agricultural activities with a high pollution potential to have a permit" (European Union, 2011). For textile industry, IPPC is effective for "plants for the pre-treatment (operations such as washing, bleaching, and mercerisation) or dyeing of fibers or textiles where the treatment capacity exceeds 10 tonnes per day". In order to operate plants within IPPC's scope should obtain an environmental permit which is based on Best Available Techniques (BAT). In 2003 the Reference Document on Best Available Techniques for the Textile Industry was released (European commission, 2010). The BAT reference document for textile industry provides information on determination of BAT in terms of resource consumption and pollutant emission levels, and some annexes providing information on textile chemicals, recipes and machinery (IPPC, 2003).

Registration, Evaluation, Authorisation and Restriction of Chemical substances (REACH)

REACH Directive (EC 1907/2006) came into force from June 2007, with the purpose to protect human health and the environment "though better and earlier identification of the intrinsic properties of chemical substances" and to promote innovation of the EU chemicals industry (European Commission, 2012). REACH is based on the ideal that industries have the ability to reduce chemical risks to humans and the environment; therefore it requires industries to comply with certain obligations to manage the risks of chemicals. Producers or importers should provide a registration dossier to the European Chemicals Agency (ECHA) if the annual production or import volume exceeds 1 t per year. The Agency will evaluate the registration dossiers in terms of compliance to the requirements and the suitableness of the proposed testing proposals. The agency and the competent authorities of member states will also evaluate the substance to clarify its risks to human health and the environment. The production or importation of Substances of Very High Concern (SVHC) should apply for authorization. If the risks from a substance are unacceptable, restriction of the production and importation of that substance in EU will take effect (European commission, 2007). A wide range of industries are affected by REACH and it undeniably increases the costs of the industries, but as a consequence it will benefit the environment and reduce health impacts on industrial workers and product consumers.

REACH directive is the first EU legislation concerning chemical content in finished

products (EPPA, 2007). Textile industry which uses a wide range of chemicals is also subject to REACH regulation (European Commission, 2010). The significance of impact of REACH to textile companies strongly depends on their position in the textile supply chain and the location of the production process. According to REACH, textile producers whose production processes are based in EU has the obligation to register chemicals sourced from non-EU suppliers if the substance volume is above 1 t per year. However, if the substance is produced by EU companies, it is the supplier's obligation to register that substance. The use of SVHC with a concentration in product above 0.1% and the total volume exceeds 1 t per year should be notified to ECHA. If the SVHC used in EU textile production is sourced from outside EU, a specific authorization is required whatever the total annual volume of that substance is. Textile production process outside EU is less impacted by REACH, whose obligation is limited to notification of SVHC. As a matter of fact, EU textile producers are more heavily affected by this legislation compared to non-EU producers, but non-EU producers have greater challenges to identify the chemical content of the their products as the tracking of information through the supply chain is very difficult in many developing countries (EPPA, 2007).

4.2 Databases

OEKOpro is an independent free online database since 1986 which is mainly financed by the German EPA. It provides information about what substances are used in what products. The OEKOpro database provides qualitative chemical information of many products, including textiles, batteries, rubber and so on. The inventory of textile chemicals contains 1970 chemical substances, provided with CAS number, commercial name, molecular formula, molecular weight, function, and applied industrial processes. Some chemicals are also provided with toxicity data (OEKOpro, 2011). However, the database doesn't provide any quantitative information of the chemicals. This database is good for understanding the chemical, physical and industrial characteristics of the chemical substances and it can serve as a qualitative data source of textile chemicals.

Commodity Guide is an open database owned by the Swedish Chemicals Agency. It provides general information to achieve the typical composition of products and materials. In this database, the section of textile and textile articles are divided into many commodity groups, e.g. dressers and ski suits. It is possible to check the composition of various substances in each commodity group, materials that may be used in a commodity group, and also substances that may be used in a material (Commodity Guide, n.d.). The drawback of this database is that the composition is expressed in a range, instead of in average values. It is worth mentioning although there are commodity groups of textile and textile articles in the database, there are no material groups for textile fibers.

Statistics Sweden has information about the import and export trade statistics according the Swedish standard classification of products by activity (SPIN 2007) and the

customs Combined Nomenclature (Statistics Sweden, 2012). Most of the data is given in monetary units but some are available in quantities. The usability of this database is to calculate the accumulated stocks of consumer goods in Sweden and to allow an estimation of accumulated stocks of chemicals in products after achieving the average chemical content in consumer goods.

4.3 Other publications and documents

Excepts for the reports released by the relevant projects introduced in Chapter 2, there are some other publications and documents which could contribute to the project. Examples of the most useful publications are listed below.

OECD Emission Scenario Document
The Emission Scenario Document (ESD) on Textile Finishing Industry was prepared by the Organisation for Economic Co-operation and Development (OECD) in 2004 in order to estimate the emission of chemicals to the environment from textile industries. Information on the sources, functions, and emission pathways of textile chemicals are provided in the document (OECD, 2004).

This document provides typical applied amounts and degree of fixation of most chemical substances used in textile manufacturing. However, this document doesn't study specific chemical substances but just the chemical groups such as textile auxiliaries, dyestuffs and so on.

BAT Reference Document (BREF)
The BAT reference documents within the scope of IPPC for textile industry contains some annexes which provide information on textile auxiliaries, dyes and pigments, textile machinery, and typical recipes and so on (IPPC, 2003). But the information is not substance based and the focus of this document is the emission during production instead of the remaining chemicals.

2003 DEPA report on survey of chemical compounds in textile fabrics
From 2002 to 2003, the Danish Environmental Protection Agency (DEPA) carried out a survey of chemicals in textile fabrics. In this project 20 textile fabrics were selected and tested for a number of organic compounds and heavy metals. As asserts by DEPA (2003), due to financial limitation, this survey was not possible to cover "all chemical compounds in all fabrics" but the idea was to cover as many as possible. This project also assessed human health risks from the detected chemicals. The test results are used as a direct information source for concentrations of some chemicals in this project.

Due to resources and time limitation, the selected target chemicals were not tested for all of the 20 fabric samples (DEPA, 2003). It is a common problem in textile testing that the test is very expensive, especially for some organic substances. Another problem is that test methods used may have different detection limits. Sometimes parallel tests

may have large deviations. Test uncertainties from sampling errors, operation errors and inhomogeneity of samples are difficult to avoid. Therefore it is very difficult to get an overview of chemicals in textile products through laboratory testing.

The report by Danish EPA gave very limited information on chemical content of synthetic fibers. Based on a worst case scenario, the chemical content information of 100% PET textile products from the DEPA's report is summarized in Appendix 4.

The book *Textile Chemicals-Environmental Data and Facts*

The book *Textile Chemicals-Environmental Data and Facts* by Lacasse and Baumann in 2004 provides wide information on chemicals used in the textile industry. The focus is the textile finishing sector which covers pretreatment, coloring and functional finishing. Legal regulations related to textile industries are also introduced (Lacasse and Baumann, 2004). In this book typical chemical content of selected chemicals and chemical groups are summarized, as shown in Appendix 4. The table provides very straightforward average chemical content information for textile products.

Although the focus of this book is the chemicals used during production and the emissions to the environment, and there is not much information on specific chemical substances, the book is a good source of fundamental information on textile manufacturing and chemicals.

Guide to Buying-terms for chemical content in textiles, clothing, leather goods and shoes

The Textiles Importers' Association of Sweden periodically publishes Guide to Buying for producers and importers in order to inform the buying terms and facilitate fulfillment of legal requirements. Chemicals of concern are described in terms of limit value, properties, functions, legal background, test method and test detection limit. In 2003 the third edition of this guide was issued and 17 banned chemicals or chemical categories were elaborated. Summary of the guide is shown in Appendix 2.

SWEREA reports

The Swedish company SWEREA/IVF made a survey on the mapping of chemicals used in clothing on behalf of KemI in 2009. Five items covered in the study are (Olsson, et al., 2009):

- Knitted T-shirts made of cotton
- Woven Jeans made of cotton
- Woven work pants made of cotton
- Knitted thin sweater made of viscose
- Shirt made of PES

The project report reviewed the chemical consumptions on different processes. It focused on the applied chemicals rather than residual chemicals in textile products. But it could be useful in terms of applied amounts of chemicals which will be introduced in

4.4 Useful tools

Chemical Abstracts Service (CAS) Registry Number

CAS Registry Number is "a unique numeric identifier" to chemical substance. The Database of CAS Registry which is owned by the American Chemical Society (ACS), covers chemical substances disclosed in scientific literatures from 1957 and is continuously updated. Substances contained in CAS Registration include "organic and inorganic compounds, metals, alloys, minerals, coordination compounds, organometallics, elements, isotopes, nuclear particles, proteins and nucleic acids, polymers, and UVCBs (materials of Unknown, Variable Composition, or Biological origin)." CAS Number is a very useful tool for communication related to chemical substances because one chemical substance may have many synonyms, but one CAS number "designates only one substance" (CAS.org, 2012).

It's also good to know that CAS Registry assigns unique CAS numbers to two types of chemical substances: substance with "completely defined molecular structures", and substance without "established molecular formulas" but whose name "clearly imply the chemical composition". This suggests that isomers of the same molecule may have different CAS number, while a class of chemical substances may be assigned the same CAS number, e,g. cellulous acetate [CASRN 9004-35-7] (CAS, n.d.).

Speaking of polymers, synthetic polymers are registered based on the monomers of the starting materials, while natural polymers are registered according to the names which imply specific and unique characteristics of the substances or the repeating structural units. Polymers with different chain length but the same repeating structural unit are assigned the same CAS number. (CAS, n.d.).

Material Safety Data Sheet (MSDS)

MSDS is an important part of product safety management. It is used for chemical producers and importers to declare the physical and chemical characteristics of their products. The MSDS could contribute to protections of the workers through providing information on harmful chemicals contained in the products, and it could facilitate emergency treatment when accident happens. Some examples of MSDS could be found online (MSDS.com, n.d.). The part "composition/information on ingredients" could be used in this project to identify the chemical content of textile products. But the investigation into several MSDS documents founds that the chemical content information is often very rough in MSDS. Usually the composition according to the MSDS is very simple, or some substances are not provided with CAS numbers and it is claimed the specific information on chemicals in products are trade secrets.

Restricted Substance List (RSL)

RSLs are usually for internal use of companies and their supply chains. The list contains chemicals that are unwanted in the products of the company. In textile industry, RSL is usually made by the company which puts textile products on the market. RSL is a kind of negative content system (UNEP, 2011.).

One example of RSL could be found on the webpage of Hemtex, a retailer of home textiles. It is declared that all the suppliers should fulfill the chemical restriction requirement in order to supply products to the company. The company will authorize external laboratories to test the products regularly against their compliance with the RSL (Hemtex,n.d).

5. Method Development

Figure 5 shows the flowchart of the method used in this project to estimate the average chemical content in textile products. The method comprises of two phases—qualitative information acquisition and quantitative information acquisition. At the beginning, information on possible residual chemicals is collected. Such information includes the names and CAS numbers of possible residual chemicals and the materials in which the chemicals can be applied to. Then the chemicals are classified according to the applied points in the manufacturing processes and their specific functions, e.g. carriers in dyeing process, antiwrinkle agent in functional finishing, etc. After that an initial qualitative chemicals list for textile products is created. The initial list covers all the common textile fibers and the next step is to define the specific textile fiber, e.g. polyesters, polyamide, etc. The fiber-specific qualitative chemicals list is constructed and updated according to literature review. This list contains possible residual chemicals on a specific textile fiber, and the chemicals are classified into functional groups. In the quantitative information acquisition phase, the first step is to collect data on applied amount and degree of fixation of each chemical group. Then the residual concentration of each chemical group could be calculated by multiplying applied amount and degree of fixation. The concentration of each chemical substance can be acquired by dividing the total concentration of a chemical functional group to the number of chemicals identified in that group. Applied amount and degree of fixation of some chemical groups cannot be found. In that case, information on detection limit of restricted substances or ready-to-use data collected from previous surveys are used to substitute the chemical concentration.

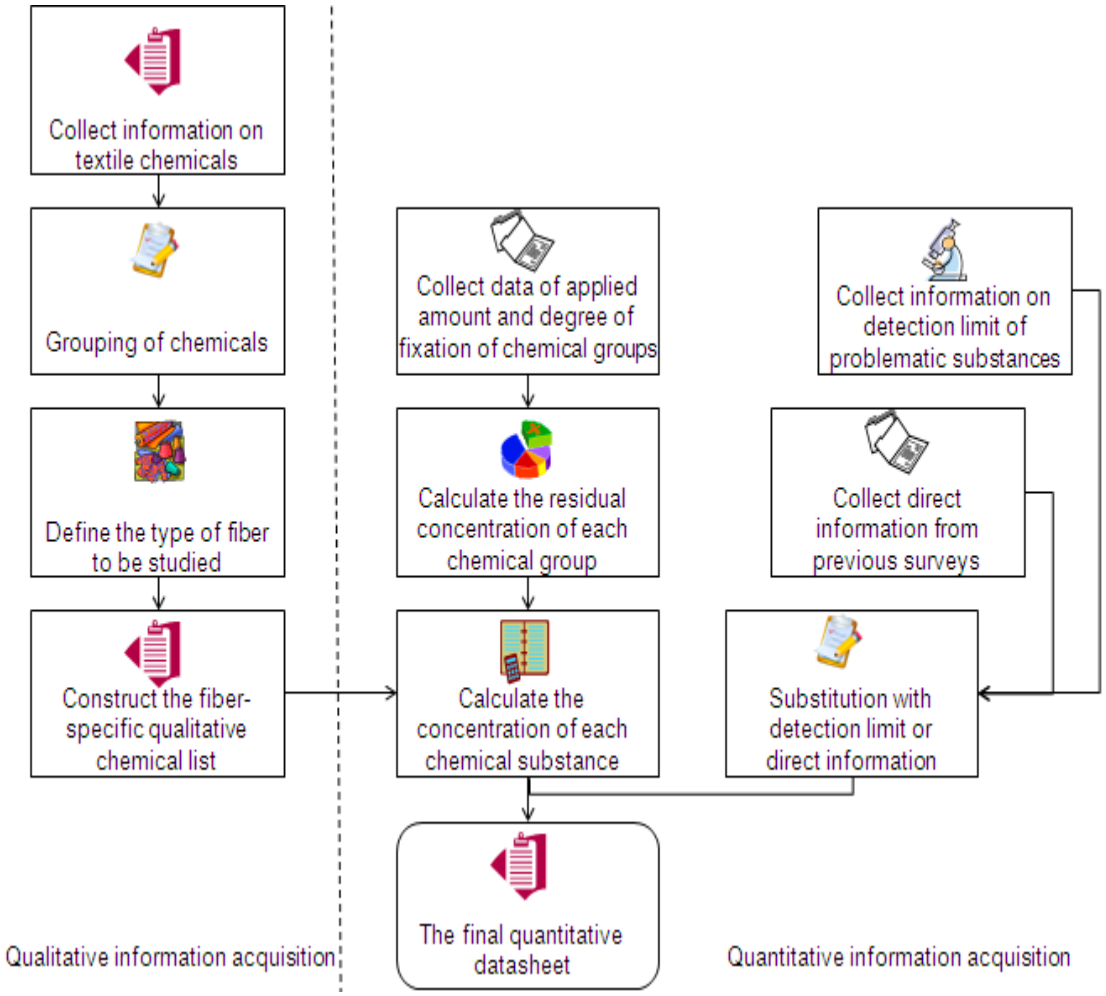

Figure 5. Flowchart of the method

5.1 Qualitative information acquisition

Qualitative information acquisition is the first phase of the method developed to estimate average chemical content in textile products. The purpose of this phase is to identify possible residual substances in finished textile products. The chemicals should be classified according to applied points in manufacturing and their functions.

5.1.1 Compiling the initial qualitative datasheet

The first step is to merge research results of the two KemI projects-Chemicals in Textiles project in 1996 and Mapping of Chemical Substances project in 2008- in order to construct a qualitative textile chemicals list. Criteria for including a substance in the list is shown in figure 6.

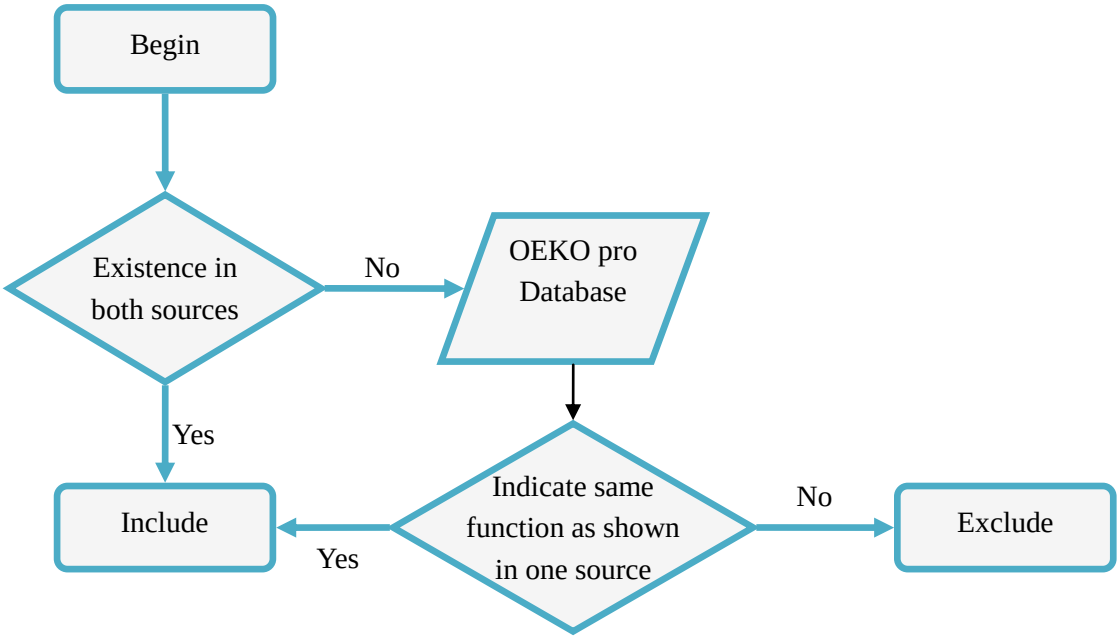

Figure 6. Criteria for including a substance in the initial qualitative datasheet

When begin to judge, if the substance exists in both sources, it will be included in the datasheet. If the substance exists in only one of the sources, the OEKOpro database will be searched. If the database also indicates same functions as shown in one source, it will be included. If not, the substance is excluded.

Although the KemI report on mapping of the chemical substances in three types of material specifies the information sources in the Excel file, but some chemicals cannot be found in the indicated sources. One example is Dimethylformamide [CAS 68-12-2] which is in the excel file as a fixing agent of textile materials but not included in the specified reference, the KemI report No 5/97 Chemicals in textiles - report of a government Commission (KemI, 1996). In order to check the validity, the database OEKOpro is searched. The searching result indicates this substance is used in battery industry, photographic industry, rubber industry, paint and coating industry and metal industry, but no mention about its use in textiles. So this substance is excluded from the qualitative datasheet.

The initial qualitative datasheet is shown in Appendix 3. The datasheet contains chemicals with a potential to remain on finished textile products and the chemicals are sorted according to the applied processes and functions. Information on the adaptability of specific chemical substances on certain textile fibers is also provided. This datasheet is valid for all the common textile fibers, but pesticides and fertilizers used in growing of cottons are not included (KemI, 1996, p18). Dyestuffs are not included as well because the number of dyestuffs is too much, as shown in Table 4 (KemI, 2008), and dyestuffs are quite fiber-specific. The application of certain dyestuff to a certain textile material should be considered case by case, which means

the general information of dyestuffs is not as meaningful as that for other auxiliaries.

Table 4. Number of dyestuffs for each textile material (Based on KemI, 2008)

Textile Material	**Cotton**	**Polyacrylic**	**PA**	**PES**	**Silk**	**Wool**	**Viscose**
Number of dyestuffs	233	33	255	239	218	233	218

Many dyestuffs can be applied on more than one textile material, and in total there are 261 dyestuffs identified by KemI (2008). Detailed information on dyestuff names, CAS numbers and the existence in each material could be found online (KemI, 2008). The presence and concentrations of dyestuffs will only be discussed in the following two case studies of polyester and polyamide rather than on a general level.

5.1.2 Compiling and update of fiber-specific chemicals list

Since some chemicals are used in specific textile fibers, a fiber-specific chemicals list needs to be established. The construction and update of fiber-specific chemicals list include phasing out impossible substances and adding substances which may be applied on the studied fibers.

Phased out unreasonable substances

When constructing the datasheet for specific textile fiber of PES or PA, substances which are not used for that type of fiber are phased out from the datasheet according to relevant literatures and legislative requirements. The legally banned substances are also treated according to the Guide to Buying and REACH legislation. If a substance is declared to be “not permitted” or “no occurrence” and no detection limits are provided, it is deleted from the chemical list. For example, substance Tris(2,3-dibromopropyl) phosphate [CAS 126-72-7] which has the function as flame retardant is restricted according to REACH as “shall not be used in textile articles, such as garments, undergarments and linen, intended to come into contact with the skin”. No detection limit is provided for this substance therefore it is phased out from the datasheet (European commission, 2012).

Add substances to the datasheets

Some substances are added to the list because the initial qualitative datasheet is not exhaustive and can be developed further. It is very likely that the two KemI reports used as basis for the initial qualitative datasheet do not cover all the possible residual chemicals in textiles due to lack of knowledge and emerging of new textile chemicals, therefore some substances are added to the datasheet if other information sources indicate their presence in textile products. This step is to refine the initial result. Information sources include various scientific literatures, databases, and so on. Substances are added to the datasheet of polyester and polyamide textile products. These newly added substances are listed in Appendix 5, in which the source of data is

also provided.

The newly added substances are checked against the Guide to Buying and REACH legislation to make sure they are not restricted. Finally a developed fiber-specific qualitative chemicals list can be constructed and made ready for quantifying of chemical concentrations in the subsequent steps.

5.2 Quantitative information acquisition

This part will discuss the three methods to estimate the concentration of the chemical substances in textile products.

5.2.1 Applied amount and degree of fixation

This method is based on mass balance of textile production which can be expressed as:

$$\text{Residual Chemicals} = \text{Input Chemicals} - \text{Output Chemicals}$$

The information on input chemical may be collected from textile industrial handbooks or other documents, and the output information may be acquired from the wastes information of textile industry. However, the waste information may be difficult to find or may be not on substance level, e.g. expressed as Chemical Oxygen Demand (COD) in textile wastewater treatment. Smith (2009) mentioned the emission of dyes to wastewater in textile industry could be calculated based on "the mass of dyestuff used per mass of goods" and "the degree of fixation". This train of thought may be applied for other chemical substances as well, as expressed by the following equation:

$$\text{Residual Chemicals} = \text{Applied Amount} * \text{Degree of Fixation}$$

Applied amount is the amount applied in the production of textile products. It is expressed as the mass of the substances used per mass of textile substrate (OECD, 2004, p42). The definition of degree of fixation is the ratio of chemicals fixed on the textile substrate to the total chemicals applied, as analogue of degree of fixation of dyes in BAT reference document (IPPC, 2003, p477). Degree of fixation of chemical substances is only approximated values, but they can be used to estimate the average chemical content in textile products.

5.2.2 Ready-to-use data

Sometimes data can be collected directly from previous surveys or consulting reports by experienced specialists. This kind of information sources may provide ready-to-use data for this project, but often the previous research findings are partial and one-sided because a single research is unlikely to cover all the possible residual textile chemicals. Some ready-to-use data collected are demonstrated in Appendix 4. The first set of data is cited from a consulting report while the second set is from field

survey. Such direct information collected could be used to check the result of this study or to be used as substitutions for some substances.

5.2.3 Detection limit

Detection limit are used for the restricted substances according to REACH legislation and the Guide to Buying by the Swedish Textile Importers´ Association. If the substance is declared to be “not permitted” or “no occurrence” and detection limit can be found, the detection limit in laboratorial test will be used to represent the concentration of that substance as a worst case scenario because there could be trace of banned chemicals in the finished products due to contamination. For example, if banned arylamines exist in the datasheet, their concentration is assumed to be the detection limit 30 ppm (European commission, 2012, p432).

6. Case study-Polyester

6.1 Polyester

The first polyester (PES) fiber was developed in 1930s and the mass production was from 1960s. The definition of PES fibers is fibers containing at least 85% of an ester of a diol and terephthalic acid (Sattler and Schweizer, 2011). PES fiber is the most widely used synthetic fiber nowadays, because of their "low costs, convenient processability, and excellently tailorable performance" (Jaffe, M. and East, A. J., 2006).

There are many types of commercially available PES fibers, including poly (ethylene terephthalate) (PET), poly (butylene terephthalate) (PBT), and polytrimethylene terephthalate (PTT), and so on. Among them PET is the main PES used in textile industry (IPPC, 2003, p17), so this report primarily focuses on PET.

PET [CAS 25038-59-9] is the condensation product from terephthalic acid [CAS 100-21-0] and ethylene glycol [CAS 107-21-1]. The structure of PET is shown in Figure 7, in which "n" is usually 80-150 (Sattler and Schweizer, 2011).

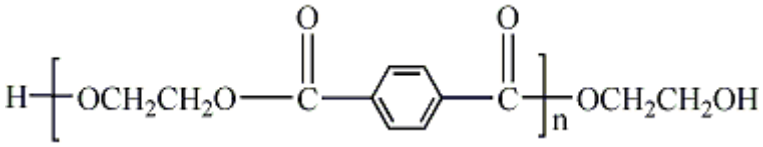

Figure 7. Molecular structure of PET (Sattler and Schweizer, 2011)

6.2 Manufacturing processes

Most manufacturing processes of polyester are similar to the general textile fibers as introduced in Chapter 3. The upstream processes contain steps from polymer production, to fiber manufacturing, yarn manufacturing and fabric production. Textile finishing includes pretreatment, coloring and functional finishing. This part will emphasize polymer production and coloring processes which are relatively more fiber-specific compared to other processes.

The PET polymer production contains two steps. The first step is transesterification and formation of bishydroxyethylter-ephthalate (BHET) and the next step is polycondensation to form PET. The reaction equations are shown in figure 8. As indicated in the figure, both steps are catalytic reactions. During the polymer production process, water should be removed carefully in order to give high molecular weight of PET. The melting point of PET is 265 ℃ which is lower than the polycondensation temperature (Sattler and Schweizer, 2011).

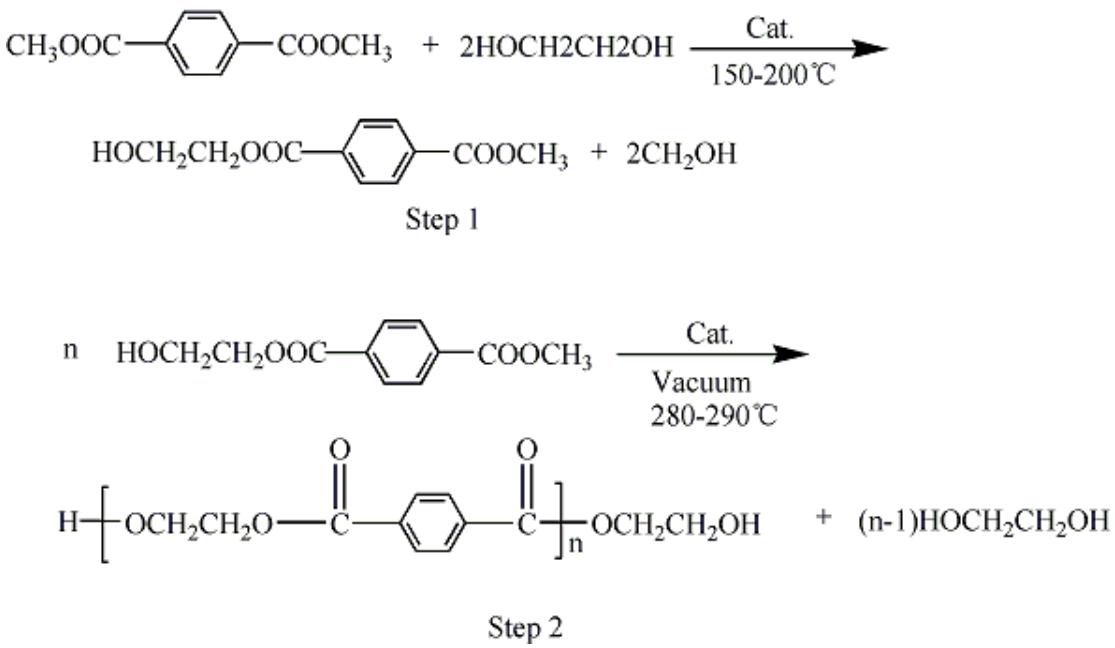

Figure 8. Reaction equations of PET polymerization (Sattler and Schweizer, 2011)

The original fiber is transparent, so fillers are added before polycondensation according to the desired colors. Commonly titanium dioxide [CAS 13463-67-7] is added in order to dull the fiber and sometimes carbon black are added for black coloration.

The polymer produced from polymerization is either chilled, cut into chips, and stored for use or they can be immediately spun into fiber and yarn. Fabrics can be produced by interlacing yarns (Jaffe, M. and East, A. J., 2006).

The pretreatment of polyester fiber or fabric is similar to the general pretreatment processes as introduced in chapter 3. Additional pretreatment for polyester textiles is alkalization which intends to improve the hydrophilicity and handle of polyester textile products. This is because original polyester is highly hydrophobic (Lacasse and Baumann, 2004, p193).

The coloring of polyester is influenced by its hydrophobicity and molecular structure as well. The only way for the application of dyestuffs on pure polyester fiber is depended on Van der Waals forces because polyester has no reactive functional groups as other fibers (Jaffe and East, 2006). Polyester fibers are hydrophobic so that highly water soluble dyes do not attach on them. The poorly water soluble dyes are used but they must be dispersed before application since most dyeing processes is carried out in aqueous liquid. Dyeing of polyester fiber requires high temperature (over 100 ℃) or using carriers because polyester fiber has a "compact structure" which leads to difficulties for the diffusion of dyestuff in the fiber (IPPC, 2003, p17). Usually, after-treatments are needed when dyeing polyester fibers in order to remove surplus dyes and increase fixation degree. The dyeing techniques for textile products made of

pure polyester are almost exclusively batch dyeing (Lacasse and Baumann, 2004, p193)

The functional treatments of polyester are also similar to the general fibers, except that the needs for synthetic fibers to be winkle-resistant and flame retardant treated are not as much as for cotton (KemI, 1996, p41). Flame retardant treatment is commonly applied for home textiles such as drapes and curtain fabrics (Sattler and Schweizer, 2011). Antistatic treatment is usually necessary for polyester fibers because PES is highly hydrophobic and the moisture regain is only 0.4% at 60% Relative Humidity. This property leads to easy building up of static electricity charges if friction happens (Jaffe and East, 2006). Antistatic agents and surfactants may be added to solve this problem (KemI, 1996, p41). The application of finishing auxiliaries is mainly by padding technology (OECD, 2004, p25).

6.3 Chemical content of PES textiles

This part provides information on textile chemicals used for polyester; discusses the selection of data for the final datasheet; and expresses how the concentrations of chemicals are achieved.

6.3.1 Chemicals from upstream processes

Polyester polymerization requires catalysts. Catalysts for the first step of polymerization are primarily zinc, calcium, and manganese acetates but they should be fully removed in subsequent processes because they can also react as depolymerization catalysts. The second step is almost exclusively catalyzed by antimony trioxide (Jaffe and East, 2006). It is estimated that more than 99.9% of the world production of PES uses antimony oxides or antimony acetates to catalyze the polycondensation of PET. The content of antimony in PET ranges from 200 to 300 ppm, but in the following wet processing, some of the antimony can be washed off (Lacasse and Baumann, 2004, p73). Antimony trioxide is also used as flame retardant (Levchik and Weil, 2005). The worst case from the Danish EPA's survey indicates the content of antimony of 215 ppm is found (DEPA, 2003). So the value will be used as the average content of antimony as a worst case scenario due to lack of other information sources.

Titanium dioxide [CAS 13463-67-7] added to dull the fiber has a typically concentration between 0.1-3% of the transesterification product (Sattler and Schweizer, 2011). A Material Safety Data Sheet of polyester fibers by the manufacturer MiniFibers which released in March of 2011 also indicated the existence of titanium dioxide in their products and the concentration by weight is estimated to be 0-5% (Minifibers, 2012). Therefore, the average concentration of titanium dioxide is assumed to be 2%.

In the polycondensation process of PET fibers, some cyclic oligomers (1-3%) are formed which is adverse for the "level dyeing and rub-fastness properties", so they are

intended to be removed before dyeing (IPPC, 2003, p17).

During the spinning of PET fibers, surfactants or lubricants are applied. Theses finishes have very complex formulation, and are usually water emulsions of various surface-active agents and lubricant oils (Jaffe and East, 2006). However, these spinning additives are usually washed out in pre-washing before processes such as bleaching and dyeing (Lacasse and Baumann, 2004, p152).

Metal impurities exist in the products from fabric preparation as indicated in the qualitative database. However mercury is removed from the list of polyester because it is seldom found in textiles, and may just occur in cotton and PVC (Hemtex, n.d.). The content of other metal impurities will be assigned 0.5ppm which is the detection limit for lead and cadmium in the Guide to Buying by the Swedish Textile Importers' Association (Textilimportörerna, 2003).

6.3.2 Chemicals from pretreatment

Some optical brighteners are added to the qualitative datasheet for polyester according to the searches in the database OEKOpro, as shown in Appendix 5. The amount of optical brighteners in a standard recipe for polyamide is 5-15g/kg textile substrate (Lacasse and Baumann, 2004, p135). The average value 1% is used as the representative value. The typical applied amount of optical brighteners for polyester is assumed to be the same as that of polyamide since there are no other information sources founded. The degree of fixation of optical brighteners is assumed to be 70% which is the typical value for a continuous pretreatment of cotton knit fabric (Lacasse and Baumann, 2004, p135).Bleaching agent and other processing chemicals are assumed not to remain in the finished products according to the criteria in subchapter 5.2.1. The average content of brighteners can be calculated after achieving the applied amount and degree of fixation.

6.3.3 Chemicals from coloring

Numerous disperse dyes are used for dyeing of polyester fibers (Lacasse and Baumann, 2004, p193). Basic dyestuffs can also be used for polyester fibers if the fiber manufacturing processes incorporate acidic components as co-monomers. (Lacasse and Baumann, 2004, p195). In this project, 284 different dyestuffs are identified for polyester textiles.

The applied amount of dyestuffs is referred from the BREF document which provides typical recipes for some textile materials (IPPC, 2003, p158-167). The table 5 summarizes the figures related to polyester fibers. The mean values of the ranges are

used as the representative values. The average content is calculated as a mean value of the two types of materials, which means dyestuff applied amounts on yarn and fabric are not distinguished, so as to simplify the problem. Therefore, the total applied amount of dyestuffs is selected to be 2.97%, and the total concentration is distributed to each substance according to the number of dyestuffs identified.

Table 5. Typical applied amount of different chemicals for polyester production (Adjusted from IPPC, 2003, p158-167)

Applied chemicals	**Ranges (g/kg)**	**Mean value (g/kg)**	**Type of Material**	**Average Content (%)**
dyestuffs	18 - 36	27	PES yarn	2.97
	15 - 50	32.5	Knitted fabrics of synthetic fibers	
textile auxiliaries	80 - 130	105	PES yarn	10.125
	45 - 150	97.5	Knitted fabrics of synthetic fibers	
basic chemicals	95 - 125	110	PES yarn	13.75
	50 - 280	165	Knitted fabrics of synthetic fibers	

The degree of fixation of dyes differs significantly for different dyes, fibers, shade and dyeing parameters applied. Generally, reactive dyes and sulphur dyes have the lowest degree of fixation (Lacasse and Baumann, 2004, p550). The values of degree of fixation of dyestuffs are taken from the OECD document (OECD, 2004, p47), but the document doesn't provide comprehensive information. When there are no values of fixation degree for some dyes or the type of dyes is not clear, for example, C.I. Mordant Yellow 16 (CAS 8003-87-0) for polyester fiber, a degree of fixation of 100% is used as a worst case scenario in order to be on the safe side when calculate the concentration of residual chemicals. The values of degree of fixation of dyestuffs for polyester are summarized in table 6.

Table 6. Degree of fixation of different dyestuffs for polyester (Adjusted from OECD, 2004, p47)

Type of dyes	**Degree of fixation (%)**	**Remarks**
Acid dyes	95	Batch dyeing, unspecified material
Azoic dyes	84	Continuous dyeing, unspecified material
Basic dyes	99	Batch dyeing, PAN,PES, PA, Cotton
Direct dyes	88	Batch dyeing, Cotton
Disperse dyes	97	Batch dyeing, PES
Other dyes	100	Assumption based on worst case

After that, the average content of dyestuffs can be calculated by multiplying the applied amount of each substance with the degree of fixation of the dye types they belong to. The result shows the total concentration of residual dyestuffs is around 2.6%. This is considered to be reasonable because the KemI report also pointed out that typical concentration of dyes lies between 0.05 to 3% depending on the type of dyes, type of

materials, and the structure of the textile (KemI, 1996, p53).

Carriers are dyeing accelerants and they can temporarily expend the fiber and “carry” the dyestuffs into the fibrous structure (Jaffe and East, 2006). Carriers are not chemically bonded to fibers. Despite the carriers are of high environmental and health concern, their application in polyester dyeing is very common (IPPC, 2003, p17). The existence of carriers in polyester could lead to a strong odour (KemI, 1996, p53). The applied amount of carriers 4.25 % is sourced from the survey by SWEREA/IVF (Olsson, et al., 2009). The degree of fixation of carriers on PES is 50% according to Lacasse and Baumann (2004, p533).

The applied amount of dyeing axillaries is estimated to be 60-70% of the consumption of the dyestuffs (Borschel, 2011). Therefore the applied amount of fixing agents which are used in after-treatment of dying and printing is estimated to be 65% of the dyes applied. The degree of fixation of textile auxiliaries used in after-treatment of dyeing processes is 90% according to OECD emission scenario document (OECD, 2004, p45).

6.3.4 Chemicals from functional finishing

Some antistatic agents are added in the datasheet for polyester according to searches in literatures, as listed in Appendix 5.

Since the need for flame retardant treatment of synthetic fibers is low, the total concentration of flame retardant is assumed to be 1% which is the lower limit of typical range of flame retardant as seen in Appendix 4. The applied amounts of other functional finishing agents are estimated to be equal and the total amount of functional finishing auxiliaries is estimated to be 2% for padding finishing (OECD, 2004, P44).

The degree of fixation of the functional finishing agents is high because they are the last step in the textile manufacturing and they are intended to stay in the finished products. According to the OECD emission scenario document, the degree of fixation of functional agents with padding technology is 100% (OECD, 2004, p45).

The concentration of functional finishing agents can be achieved by multiplying the applied amount and degree of fixation.

6.4 Results and analysis

Table 7 summarizes the applied amount, degree of fixation and concentration of each chemical group for polyester. In the brackets the references are also given. Ranges of data are provided in the square brackets if available. The concentration of polymer substrate is calculated by 1 minus the total concentration of all the other chemicals.

The average chemical content in polyester textile products is demonstrated in Figure 9. Polymer substrate PET [CAS 25038-59-9] accounts for the largest proportion. Apart from the substrate, most residual chemicals are from the coloring processes. Most pretreatment agents are removed in subsequent processes, therefore the residuals, mainly brighteners, just accounts for small part of the finished products. Fillers and impurities account for 2.3% while functional finishing substances take up 2%.

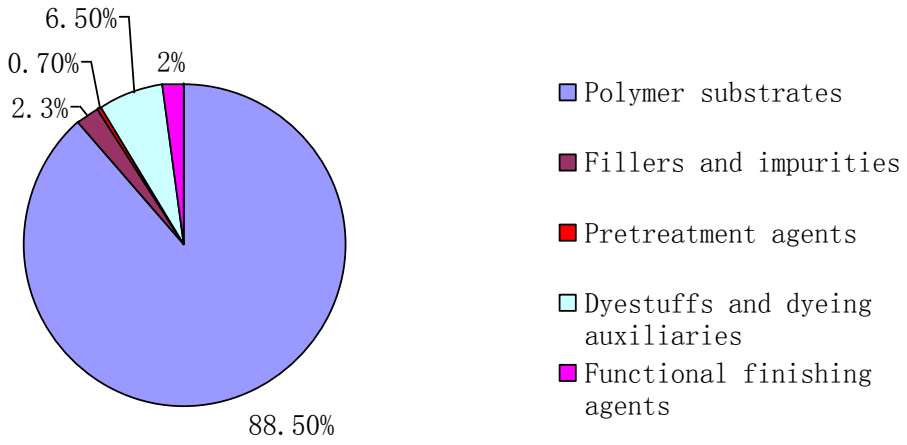

Figure 9. Average chemical content in polyester textile products

The final quantitative datasheet for polyester is seen in Appendix 6. Problematic substances whose concentration is substituted by detection limit are marked red. Apart from the polymer substrate, 366 chemicals are indentified as residual chemicals in polyester textiles on an average level, and the total concentration is 11.5 % of the textile substrate. CAS numbers of these chemicals are provided. Despite the list contains 366 chemicals, It does not mean any textile products will contain all of these chemicals, and it does not mean substances not included in this list cannot be found on polyester textile products in reality either.

Table 7. Applied amount, degree of fixation and concentration of each chemical group for polyester

Application process	**Functions**	**Applied amount**	**Degree of fixation**	**Concentration**
Fabric preparation	Fillers	/	/	2% [0.1%~5%] (Estimated from Sattler and Schweizer, 2011, for PES)
	Impurities	/	/	0.3% (DEPA, 2003)
Pretreatment	Brightener	1% [0.5%~1.5%] (Lacasse and Baumann, 2004, p135, for PA)	70% (Lacasse and Baumann, p500, for cotton knit fabric)	0.7% [0.35%~1.05%]
Coloring	Oxidizing / Reducing agent	/	0 (OECD,2004,p45, for basic chemicals)	0
	Carriers	4.25% (Olsson, E., et al., 2009, for PES)	50% (Lacasse and Baumann, 2004, p533, for PES)	2.125%
	Fixing agent	1.93% [1.78%-2.08%] (Estimated from Borschel, 2011)	90% (OECD,2004,p45,Textile auxiliaries used in after-treatment of dyeing processes)	1.74% [1.60%~1.87%]
	Dyestuffs	2.97% [1.5%~5%] (Estimated from IPPC, 2003, p158-167, for PES)	Various, see table 6. [84%~100%]	2.635 % [1.26%~5%]
Finishing	Flame retardants	1% [0.1%~1%] (Estimated, see chapter 6.3)	100% (OECD,2004,p45, for padding functional agents)	1% [0.1%~1%]
	Impregnating agent(repellent)	0.25% (Estimated, see chapter 6.3)	100% (OECD,2004,p45, for padding functional agents)	0.25%

	Antiwrinkle agent	0.25% (Estimated, see chapter 6.3)	100% (OECD,2004,p45, for padding functional agents)	0.25%
	Antimicrobial	0.25% (Estimated, see chapter 6.3)	100% (OECD,2004,p45, for padding functional agents)	0.25%
	Antistatic	0.25% (Estimated, see chapter 6.3)	100% (OECD,2004,p45, for padding functional agents)	0.25%
Multipurpose auxiliaries	Washing and chemical additives in formulations	/	/	0.7 ppm (Olsson, E., et al., 2009, for PES)
	Solvents	/	0 (OECD,2004,p45, for Textile auxiliaries not intended to fix)	0
Polymer Substrate		/	/	88.5% [82.7%~93.2%]

7. Case study-Polyamide

7.1 Polyamide

The production of the first type of synthetic fiber-Nylon by the American company Du Pont in 1935 is regarded as an important milestone in polymer chemistry. The characteristic of polyamide is the recurring amide linkage (-CO-NH-). Polyamides are usually referred as nylon or aramid. Nylons are aliphatic polyamides generated from aliphatic monomers while aramids are aromatic polyamides in which more than 85% of the amide linkages are directly connect to aromatic structures (Yang, 2006). Nylon is the main type of polyamide produced so this project has a focus on nylon.

The main constituent of Nylon is PA fibers which is made from a diamine and a dicarboxylic acids $(CON\text{-}H\text{-}R\text{-}NHCO\text{-}R')_n$ or lactams $(RCONH)_n$. There are a variety of diamines and dicarboxylic acids, so a large number of polyamides exist. (Hedge, et al., 2004). There could be unlimited types of PA materials with different monomers (Melvin, et. al., 2003). Generally, polyamides have the properties of being tough, semitransparent, semicrystalline, moderate cost, and easy to manipulate in melt processing (Weber, 2011)

If the polyamides are formed by diamines and dicarboxylic acids, it is called AABB type of PA. If made from diamines and lactams, it is termed AB type. Nylon-6 [CAS 25038-54-4] is an AB type polyamide made from caprolactam and Nylon-6,6 [CAS 9011-56-6] is an AABB type polyamide made from hexamethylenediamine and adipic acid. They have the same empirical formula and density but different melting point (nylon-6 220 ℃ and nylon-6,6 260℃). Nylon-6 and Nylon-6,6 accounts for nearly 98% of polyamides produced, and 70% of nylon fibers is Nylon-6 while 30% is Nylon-6,6. They are widely applied in clothing, carpet and also transportation industries. Compared to other synthetic fibers, nylon fibers have higher strength, durability, resilience properties and they are easy to dye (Anton and Baird., 2005).

The molecular structural formulas of Nylon-6 and Nylon-6,6 are demonstrated in figure 10 (Yang, 2006):

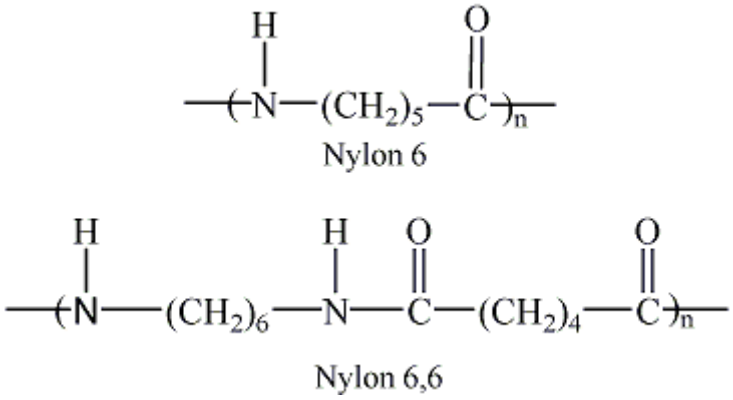

Figure 10. Molecular structure of Nylon-6 and Nylon-6,6 (Adjusted from Yang, 2006)

7.2 Manufacturing processes

The manufacturing of polyamide is similar to polyester, so this part will just introduce the special processes of polyamide manufacturing.

Nylon-6,6 polymer is made through polycondensation of hexamethylene diamonium adipate salt with water removal. The salt is heated in an evaporator at 150-160 ℃. Water is evaporated and the salt is concentrated. Additives including chain terminators, antioxidants are added. Then delusterants are added to dull the polymer. After achieving the desired molecular weight, the polymers are extruded as ribbon, cooled and cut into flakes. Nylon-6 polymer is formed by ring-opening polymerization of ε-caprolactam. The polymerization is usually initiated by water. The monomers are heated at 250-280 ℃ with the presence of 5-10% water. The produced nylon-6 polymers is extruded as strand, chilled, and cut into chips (Anton and Baird, 2005).

The fiber and yarn manufacturing with PA polymers are also mostly by melt spinning technology. The polymers are melted and transported through a spinneret to form filaments. The spinning temperature for nylon-6 is around 260 ℃, and for nylon-6,6 is 290 ℃.

The fabric formation and pretreatment of polyamide is similar to polyester, except that specific chemical substances used may be different.

The dyeing of polyamide fibers are easy because of their functional groups -CO-NH- and NH_2- may react with acid, reactive, 1:2 metal-complex dyes. And because PA fibers are hydrophobic, disperse dyes can be used. Basic dyes can be applied provided the PA fiber is chemically modified by incorporation of sulphonic acid groups. (Lacasse and Baumann, 2004, p188).Around 30% of PA fibers are dyed with 1:2 metal-complex dyes (Lacasse and Baumann, 2004, p191). Dyeing techniques for polyamide fibers are mostly batch techniques (Lacasse and Baumann, 2004, p189).

The functional finishing of PA is similar to PES. The moisture regain of PA is

approximately 3-4% at 65% relative humidity which is relatively higher than PES, but still low. Antistatic treatment of PA is necessary since the electrical conductivity is low and static electrical charges accumulate on the surface when rubbing it (Anton and Baird, 2005).

7.3 Chemical content of PA textiles

This subchapter discusses some special chemicals used for polyamide fiber, expresses the selection of data and demonstrates the calculation of chemicals concentrations.

7.3.1 Chemicals from upstream processes

After polymerization of polyamide polymer, around 8% of monomers and 2% of oligomers remain, but the residual monomers are usually removed before spinning (Anton and Baird., 2005). The content of caprolactam oligomers (CAS 105-60-2) in nylon-6 fiber is up to 1%. (Lacasse and Baumann, 2004, p73)

Titanium dioxide (TiO_2) is also used as a delustering additives for nylon. The content of titanium dioxide in semidull nylon yarns is 0.3%, in middull nylon is 1.0% and in fulldull nylon is 1.5-2% (Anton and Baird., 2005). The average value 1% is taken since there is no information on the share of each type of nylon.

During the fiber and yarn manufacturing, spinning finishes are applied after quenching of the filaments from the spinneret. A finishing emulsion contains antistatic agent, lubricant oils and so on. These spinning finishes are usually water-based therefore they will be washed out in subsequent processes.

The concentration of metal impurities is treated similar to polyester, using the detection limit to represent a worst case scenario.

7.3.2 Chemicals from pretreatment

Some optical brighteners are added to the qualitative datasheet for PA according to searches in the database OEKOpro. According to Lacasse and Baumann (2004, p135) the amount of optical brighteners in a standard recipe for polyamide is 5-15g/kg textile substrate. The average value 1% is used as the representative value. The degree of fixation of optical brighteners is assumed to be 70% which is the typical value for a continuous pretreatment of cotton knit fabric (Lacasse and Baumann, 2004, p135).Bleaching agent is assumed not remaining in the finished products according to the criteria in subchapter 5.2.1.

7.3.3 Chemicals from coloring

Polyamide fibres can be dyed with many types of dyestuffs. In this project, 255 different dyestuffs are identified.

The applied amount of dyestuffs is selected to be 3.25% as the typical applied amount of dyestuffs for knitted fabrics of synthetic fibers (See table 5). Then the average chemical content of each dyestuff could be calculated by distributing the total applied amount to the number of dyestuffs identified.

The average degrees of fixation of different type of dyes for PA fibers are listed in table 8 (OECD, 2004, p47). Same as for polyester, when degree of fixation of certain dyes cannot be found, the degree of fixation is assumed to be 100% in order to be on the safe side.

Table 8. Degree of fixation of different dyestuffs for polyamide (Adjusted from OECD, 2004, p47)

Type of dyes	**Degree of fixation (%)**	**Remarks**
Acid dyes	90	Batch dyeing, PA, PAN
Azonic dyes	84	Continuous dyeing, unspecified material
Basic dyes	99	Batch dyeing, PAN,PES, PA, Cotton
Direct dyes	88	Batch dyeing, Cotton
Disperse dyes	97	Batch dyeing, PES
Reactive dyes	75	Batch dyeing, Cotton
Other dyes	100	Assumption based on worst case

The concentration of each dyestuff can be calculated as a result.

The use of carriers for polyamide fibers is not as common as for polyester because polyamide fibers are easy to dye, thus carriers are not considered in the estimation of average chemical content in polyamide textile products.

The applied amount of fixing agent is also assumed to be 65% of the dyes applied as for polyester, and the degree of fixation is 90% according to OECD document (OECD, 2004, p45)

7.3.4 Chemicals from functional finishing

Several antistatic agents are added in the datasheet for polyamide according to searches in literatures, as listed in Appendix 5.

The functional finishing for polyamide is similar to polyester. The groups of functional finishing agents covered are flame retardants, repellent, antiwrinkle agent,

antimicrobial agent and antistatic agent. The total amount of functional finishing auxiliaries is 2% for padding finishing according to OECD emission scenario document (OECD, 2004, P44).The applied amount of flame retardants is also assumed to be 1% which equals to the lower limit of typical range of flame retardant in Appendix 4. Other functional finishing agents are assumed to have equal applied amount, which is 0.25% each.

The degree of fixation of the functional finishing agents is high because they are the last step in the textile manufacturing and they are intended to stay in the finished products. According to the OECD emission scenario document, the degree of fixation of functional agents with padding technology is 100% (OECD, 2004, p45).

The concentration of functional finishing substances in the fabric can be achieved by multiplying the applied amount and degree of fixation.

7.4 Results and analysis

Table 9 summarizes the applied amount, degree of fixation and concentration of each chemical group for PA. In the brackets the references are also given. Ranges of data are provided in the square brackets if available. The concentration of polymer substrate is calculated by 1 minus the sum content of all the other chemicals.

The average chemical content in PA textile products is illustrated in figure 11. Polymer substrates nylon-6 [CAS 25038-54-4] and nylon-6,6 [CAS 9011-56-6] account for the largest proportion. Their respective percentage is 63.4% and 27.2% if take into account of the share "nylon-6: nylon-6,6=70%:30%" provided by Anton and Baird (2005). Except for the substrate, most residual chemicals in PA textile products are also from the coloring processes. Residual dyestuffs and dyeing auxiliaries are less than those in PES because carriers are not taken into account. Most pretreatment agents are removed in subsequent processes, therefore the residuals just accounts for 0.7% of the finished products. Fillers and functional finishing agents take up 2% respectively.

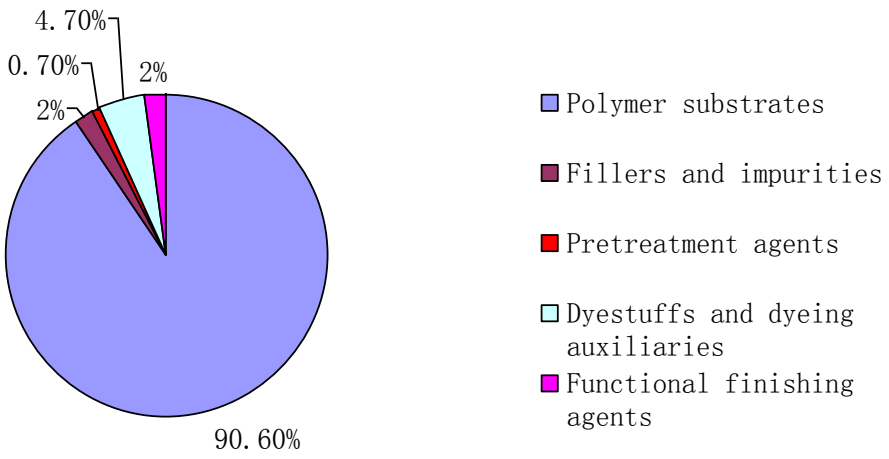

Figure 11. Average chemical content in polyamide textile products

The final quantitative datasheet for polyamide is seen in Appendix 7. Restricted substances whose concentration is substituted by detection limit are marked red. Except for the polymer substrate, 343 chemicals are indentified as remaining chemicals in polyamide textile products on an average level, and the total concentration is 9.4%. All of these substances are provided with CAS numbers. The chemicals list represents average chemical content in polyamide textile products rather than a realistic recipe.

Table 9. Applied amount, degree of fixation and concentration of each chemical group for polyamide

Application process	**Functions**	**Applied amount**	**Degree of fixation**	**Concentration**
Fiber production	Caprolactam oligomers	/	/	1% [0~1%] (Lacasse and Baumann, 2004, p73)
	Fillers	/	/	1% [0.3%~2%] (Estimated from Sattler and Schweizer, 2011, for PES)
	Impurities	/	/	Trace (Textilimportörerna, 2003)
Pretreatment	Brightener	1% [0.5%~1.5%] (Lacasse and Baumann, 2004, p135, for PA)	70% (Lacasse and Baumann, p500, for cotton knit fabric)	0.7% [0.35%~1.05%]
Coloring	Oxidizing / Reducing agent	/	0 (OECD,2004,p45, for basic chemicals)	0
	Fixing agent	2.11% [1.95%~2.28%] (Estimated from Borschel, 2011)	90% (OECD,2004,p45,Textile auxiliaries used in after-treatment of dyeing processes)	1.89% [1.76%~2.05%]
	Dyestuffs	3.25% [1.5%~5%] (Estimated from IPPC, 2003, p158-167, for Knitted fabric of synthetic fibers)	Various, see table 8 [75%~100%]	2.81% [1.125%~5%]
Finishing	Flame retardants	1% [0.1%~1%] (Estimated, see chapter 7.3)	100% (OECD,2004,p45, for padding functional agents)	1% [0.1%~1%]
	Impregnating agent(repellent)	0.25% (Estimated, see chapter 7.3)	100% (OECD,2004,p45, for padding functional agents)	0.25%

	Antiwrinkle agent	0.25% (Estimated, see chapter 7.3)	100% (OECD,2004,p45, for padding functional agents)	0.25%
	Antimicrobial	0.25% (Estimated, see chapter 7.3)	100% (OECD,2004,p45, for padding functional agents)	0.25%
	Antistatic	0.25% (Estimated, see chapter 7.3)	100% (OECD,2004,p45, for padding functional agents)	0.25%
Multipurpose auxiliaries	Washing and chemical additives in formulations	/	/	0.7 ppm (Olsson, E., et al., 2009, for PES)
	Solvents	/	0(OECD,2004,p45, for Textile auxiliaries not intended to fix)	0
Polymer Substrate		/	/	90.6% [86.9%~95.4%]

8. Discussion

8.1 Uncertainties of the results

The result could never be exhaustive and comprehensive when one intends to explore the average chemical content in products on a society level at current situation, because there are too many consumer products, too different ingredients and lack of necessary information systems. There must be some chemicals remaining in textile products in reality that are not covered in the results of this study, but the study endeavored to cover chemicals which are most frequently used and possibly remained on finished textile products. There are high uncertainties in the result. Sources of the uncertainties are analyzed below.

Uncertainties from information sources
There may be uncertainties lying in the information sources. The two KemI reports are used as a basis for qualitative information of residual chemicals in textile products. However it is very likely that some chemicals used in reality are not covered by the two reports. The estimation method according to applied amount and degree of fixation refers most data from the OECD emission scenario document. As the focus of that document is the emitted amount of chemicals, it is possible that the degree of fixation is underestimated in order to be on the safe side. This would lead to underestimation of residual chemicals in finished textile products which is the focus of this study.

Uncertainties of the estimation method
In the estimation method, the concentration of a specific chemical substance is acquired by dividing the total concentration of the chemical group by the number of chemicals contained in that group; therefore the concentration of each substance highly depends on the number of substances identified in a functional group. For example, only two brighteners for each fiber are identified, which gives rise to the high concentration-3500ppm. This is perhaps too high for a single substance. The number of chemical substances indentified as residual chemicals in textile products are just around 400 which accounts for only small part of chemicals applied in textile industry.

Uncertainties can also come from the estimation of chemical concentration when utilizing the parameters of applied amount and degree of fixation. The applied amounts of chemicals by different producers are very different. Generally, large producers and holders of eco-labels are more environmental responsible compared to small producers, therefore they probably has more efficient chemical utilization technologies. To find out the accurate average application level is not easy. The degree of fixation is only approximated values as acknowledged in the BAT reference document (IPPC, 2003, p78). It is very difficult to get accurate values of degree of fixation because they are associated with the properties of the chemicals, the types of fibers, and the way chemicals are applied in the manufacturing processes.

Substitution with detection limit would lead to an overestimation of substance concentration if producers abide by legal requirements or underestimation if tests are

not fully conducted. The performance of textile producers and importers and the status of compliance to the legal requirements are difficult to know.

Uncertainties due to lack of knowledge

There are also uncertainties owing to lack of knowledge. Information on the share of different textile products is difficult to gather, such as the share of textile products in different colors, or the share of products being functionally treated. On a general basis they are distributed equally in this estimation method. For example, the applied amount of each dyestuff is calculated by means of dividing the total applied amount by the number of dyestuffs; and the antiwrinkle agents, repellents, antimicrobials, and antistatic agents are assumed to have the applied amount of 0.25% each equally. Printing pigments are not included in the final datasheets because it is difficult to know the percentage of finished textile products being printed.

The research method of this study is mainly based on literature review, and the success of this project highly relies on the research findings from previous surveys. Generally, knowledge on residual chemicals in textile products needs to be developed further to allow a more accurate estimation of average chemical content in textile products.

8.2 Applicability of the method to other consumer products

The method for estimation of average chemical content developed in this project is also adoptable for other consumer products. One example of plastic products will be discussed below.

The KemI project Mapping of Chemical Substances in 2008 (KemI, 2008) constructed an Excel file which contains the possible remaining chemicals in three categories of consumer goods: plastics, rubbers, and textiles. The datasheet for plastics lists the chemical substances which are classified according to their functions and materials. For example, the plastic material Polyethylene (PE) contains the following groups of chemicals: antiblocking additive, antifogging additive, antioxidant, antistatic additive, flame retardant, filler, plasticizer, pigment, lubricant, stabilizer, and brightener.

For each of these functional groups, several chemical substances are listed. This datasheet could be used as an initial qualitative datasheet. And the updating of this datasheet could be done through study of relevant literatures and documents.

The concentration of these chemicals can also be calculated with the mass balance method. The OECD emission scenario document on plastics additives (OECD, 2009) provides information on the applied amount of additives for each type of plastics material and the loss factors of additives during manufacturing, use, and disposal. For example, applied amount of flame retardants for Low-Density Polyethylene (LDPE) for electrical use is 20% as expressed by the weight percentage. The loss of flame retardant during manufacturing of plastics is divided into three processes: raw materials handling, compounding, and conversion. The loss factors for each process are given. Therefore the remaining plastic additives after manufacturing can be calculated with this method. For the detection limit of some problematic substances, the REACH restriction substances list could also be used.

9. Conclusion

Knowledge on the average chemical content in textile products or other consumer goods play a crucial role in management of chemicals used in daily life. After acquisition of the average chemical content in each product category, the accumulated stocks of chemicals in products can be calculated while taking into account the accumulated stocks of products in society. The estimation of emitted chemicals from consumer goods can thereafter be done with certain emission models.

However, the task to estimate the average chemical content in any product categories is not easy. There have been some projects involving chemicals in products, but they generally end up by recommendation of what should be done to achieve the desired information, saying information systems on chemicals in products should be improved further.

In this project, residual chemicals on finished textile products are investigated. The focus is not only the harmful substances, but a comprehensive mapping of chemicals in textile products.

The investigation into the manufacturing processes of textiles founds that textile production is quite complicated and many chemicals are applied in different steps. The textile finishing which includes pretreatment, coloring, and functional finishing is the process where most chemicals are utilized, except for the polymer substrate. Some washing steps are implemented to fulfill the quality requirement during manufacturing, which further complicate the question on how much chemicals are remained.

Despite the complexity of the problem, a method is developed to estimate the average chemical content in textile products. Generally the method follows a step by step basis. Firstly a qualitative datasheet is established which contains possible residual chemicals, categorizing according to their functions and application points. The datasheet is updated and refined through taking into account of more information systems. Then for the quantifying of each chemical substance, three methods are applied. The mass balance method is to calculate the concentration of remaining chemicals by multiplying the applied amount and degree of fixation which are gathered from relevant documents. The utilization of ready-to-use data is to refer data directly from previous surveys. The substitution with detection limit is to assign the problematic substance a concentration equal to the detection limit as provided in legislations or regulations.

Two case studies are elaborated for textile products made of the two most frequently used synthetic fibers-polyester and polyamide. The average chemical content in textile products made of polyester fibers is 88.5% polymer substrate, 2.3% fillers and impurities, 0.7% pretreatment agents, 6.5% dyestuffs and dyeing auxiliaries, and 2% functional finishing agents. 366 chemicals are identified as residual chemicals in polyester textile products. The average chemical content in polyamide textiles is 90.6% polymer substrate, 2% fillers and impurities, 0.7% pretreatment agents, 4.7% dyestuffs and dyeing auxiliaries, and 2% functional finishing agents. 343 residual chemicals are identified in polyamide textile products. Generally the total concentration of a chemical functional group is distributed equally according to the number of substances identified in that group except for the problematic substances which are regulated with

limit values.

The result is rough due to the accessibility of information sources and insufficient knowledge in this field. High uncertainties can originate from information sources, the estimation method, and due to lack of knowledge. However the method is generally useful to estimate the average chemical content in textile products and it is also applicable to other consumer goods provided relevant data is accessible.

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Appendix 1. The properties and applications of different dyestuffs

The following table 10 lists the applications, properties of various dyestuffs and their bonds to fibers (Lacasse K, and Baumann W, 2004, p268-353).

Table 10 Detailed properties and applications of different dyestuffs (Lacasse K, and Baumann W, 2004, p268-353).

Dyestuff class	**Applications**	**Properties**	**Bonds to fibers**
Acid dyes	Polyamide (70-75%); Wool (25-30%); also used for silk and modified acrylic fibers.	Bright colors; Poor to excellent fastness to light and washing.	Ionic bonds between sulphonate anions and the ammonium groups of the fibers. Van der Waals forces due to high molecular weight.
Basic (cationic) dyes	Formally used for silk and wool; Now mostly for polyacrylic fibers.	Excellent fastness on polyacrylic fibers; poor fastness on silk and wool.	Ionic bonds between the cation in the dyes and the anionic site on the fiber.
Direct (substantive) dyes	Cotton, rayon, linen, jute, silk and PA.	Bright and deep colors. Low wash fastness unless after-treated.	Van der Waals forces and hydrogen bonds.
Disperse dyes	PES, cellulose, PA, acrylic fibers.	Good light fastness. Wash fastness depends on fibers.	Van der Waals forces, hydrogen bonds, dipole-dipole interactions.
Metal-complex dyes	Wool, silk. 30% of PA is dyed with 1:2 metal-complex dyes.	Excellent light fastness. Not very good wash fastness.	Forming strong co-ordination complexes with trivalent transition metal ions
Mordant dyes (chrome dyes)	Wool, silk. No longer used for PA.	Dark shades (green, blues, and black); Excellent light fastness. Very good wash fastness.	Ionic bonds between anionic groups of the colorant and ammonium cations on the fibers. Coordination bonds.

Naphthol dyes (azoic dyes)	Cellulous fibers, rayon, linen, and PES	Good light, chlorine and alkali fastness. Poor rubbing fastness. Excellent wash fastness.	Chemically bonded (KemI, 1996, p35).
Reactive dyes	Cotton, rayon, wool, silk and PA	High wet fastness.	Covalent bonds
Vat dyes	Cotton, and PA, PES blends with cotton	Excellent fastness.	Physically bonded (KemI, 1996, p35)
Sulphur dyes	Cotton, viscose, PA, PES, silk	Dark shades. Very good wash fastness. Moderate to good light fastness.	Physically bonded (KemI, 1996, p35)

Appendix 2. The banned substances according to Guide to Buying

This appendix is a summary of the third edition of "Guide to Buying Terms for the chemical content in textiles, clothing, leather goods and shoes" by the Textile Importers ´Association in Sweden (Textilimportörerna, 2003).

Table 11.List of banned substances (Textilimportörerna, 2003)

Chemical		**Use for textiles**	**Limit value**	**Detection limit**
Process chemicals	Chromium VI (Cr^{+6})	Oxidation agent. Fixing chemicals.	May not be used in processes (0).	3mg/kg
	Nonylphenol ethoxylate	Dispersing and emulsifying agent in textile chemicals. Impregnation agent in printing pastes.	May not be used in processes (0).	10mg/kg of sewage sludge
	Organic solvents	Solvents for dyeing and printing.	No more than 5% by weight of aromatic hydrocarbon in the organic solvent.	Unspecified.
	Organochlorines	Solvents for grease and oil, eg. in stain removers. Used in cleaning agents and detergents. Solvents lubrication oils. Solvents in dyeing of synthetic fibers (carriers). Solvents in printing. Finishing agents: fabric softeners, flame retardants.	May not be used in processes (0).	Unspecified.
	Pentachlorophenol (PCP)	Fungicide for rot-proofing treatment of goods prior to storage and transport. Preservative in sizing agents and adhesives. Component in printing pastes (thickener).	May not be used in processes (0).	EU legal limit 0.1%. Banned in Sweden. Detection limit

				0.5mg/kg
	2,3,5,6-tetrachlorophenol	Fungicide for rot-proofing treatment of goods prior to storage and transport. Preservative in sizing agents and adhesives. Component in printing pastes (thickener).	May not be used in processes (0).	0.5mg/kg
Product-related chemicals	20 Allergenic disperse dyes	Dyeing of textile goods	Not permitted as additives (0) in textiles or in textile toys for children under the age of two. 100mg/kg for all other textiles and textile toys.	Unspecified.
	Azo dyes degradable to carcinogenic arylamines	Dyeing. Constituent of dyes, mainly direct dyes or acid dyes.	Not permitted as additives (0).	30 mg/kg
	Cadmium (Cd)	Pigment in coloring agent.	Not permitted as additives (0).	0.5 mg/kg
	Flame retardants	Flame-retardant treatment of products.	No occurrence of substituted flame retardants.	Unspecified.
	Formaldehyde	Shrinkage-resistant treatment. Wrinkle-resistant treatment. Dirt-repellent treatment. Dye fixing agent. Preservative.	20mg/kg for textiles and textile toys for children under the age of two. 100mg/kg for all textiles that come into direct contact with the skin during normal use and for textile toys for children older than two years of age. 300mg/kg for all other textiles and for leather goods.	Unspecified.
	Nickel (Ni), in accessories	Improving alloys used in clothing accessories such as zippers, buttons and rivets.	A product may emit no more than 0.5 mg/cm2 per week.	Unspecified.
	Plastic additives-	Additives in plastics. Cadmium stabilizers, for example, increase the life	Not permitted as additives (0).	0.5mg/kg

	Cadmium stabilizers	of the material.		
	Plastic additives-Lead stabilizers	Additives in plastics. Lead stabilizers, for example, increase the life of the material.	Not permitted as additives (0).	0.5mg/kg
	Plastic additives-Phthalates	Plasticizers in plastics. Additives in adhesives, paints, lacquers, varnishes, and solvents.	No occurrence of substituted phthalates: DEHP(CAS 117-81-7), DBP (CAS 84-74-2), and BBP (CAS 85-68-7)	Unspecified
	Perfluorooctane sulfonate (PFOS) and other fluorocarbons	Additives in cleaning agents, ant poisons, film, fire extinguishing agents and impregnation agents in leather and textiles.	Not permitted as additives (0).	Unspecified
	Tributyltin oxide	To counteract noxious odours in clothes and shoes. Preservative, fungicide and antifouling agent.	Not permitted as additives (0).	0.5mg/kg
Miscellaneous	pH	/	4.0-8.0 for textiles	/

Table 12. List of banned allergenic disperse dyes (Textilimportörerna, 2003)

C.I. Generic name	***C.I.number***	***CAS No***
C.I.Disperse Blue 1	C.I.64 500	2475-45-8
C.I.Disperse Blue 3	C.I.61 505	2475-46-9
C.I.Disperse Blue 7	C.I.62 500	3179-90-6
C.I.Disperse Blue 26	C.I.63 305	3860-63-7
C.I.Disperse Blue 35		12222-75-2
C.I.Disperse Blue 102		12222-97-8
C.I.Disperse Blue 106		12223-01-7
C.I.Disperse Blue 124		61951-51-7
C.I.Disperse Orange 1	C.I.11 080	2581-69-3
C.I.Disperse Orange 3	C.I.11 005	730-40-5
C.I.Disperse Orange 11		82-28-0
C.I.Disperse Orange 37/76		12223-33-5
C.I.Disperse Red 1	C.I.11 110	2872-52-8
C.I.Disperse Red 11	C.I.62 015	2872-48-2
C.I.Disperse Red 17	C.I.11 210	3179-89-3
C.I.Disperse Yellow 1	C.I.10 345	119-15-3
C.I.Disperse Yellow 3	C.I.11 855	2832-40-8
C.I.Disperse Yellow 9	C.I.10 375	6373-73-5
C.I.Disperse Yellow 39		12236-29-2
C.I.Disperse Yellow 49		54824-37-2

Table 13. List of banned arylamines (Textilimportörerna, 2003)

Substance	***CAS No***
biphenyl-4-ylmanine	92-67-1
bbenzidine	92-87-5
4-chloro-o-toluidine	95-69-2
2-naphthylamine	91-59-8
o-aminoazotoluene	97-56-3
5-nitro-o-toluidine	99-55-8
4-chloroaniline	106-47-8
4-methoxy-m-phenylenediamine	615-05-4
4,4-methylenedianiline	101-77-9
3,3-dichlorobenzidine	91-94-1
3,3-dimenthoxybenzidine	119-90-4
3,3-dimenthylbenzidine	119-93-7
4,4-methylenedi-o-toluidine	838-88-0
6-methoxy-m-toluidine	120-71-8
4,4-methylene-bis-(2-chloroaniline)	101-14-4
4,4-oxydianiline	101-80-4
4,4-thiodianiline	139-65-1
o-toluidine	95-53-4
4-methyl-m-phenylenediamine	95-80-7
2,4,5-trimethylaniline	137-17-7
o-anisidine	90-04-0
4-aminozaobenzene	60-09-3
2,4 xylidine	95-68-1
2,6 xylidine	87-62-7

Appendix 3. The initial qualitative datasheet for the most common textile fiber materials

Table 14 is the initial qualitative chemicals list which contains information on name and CAS number of possible residual chemicals in textile products. Chemicals are classified according to application points and functions. The materials in which a specific chemical may occur are also indicated.

Table 14 The initial qualitative chemicals list

Processes	**Functions**	**Substances**	**Trade name**	**CAS**	**Materials**
Fiber Production	Impurities	Lead		7439-92-1	unspecified
	Impurities	Cadmium		7440-43-9	unspecified
	Impurities	Mercury		7439-97-6	unspecified
	Impurities	Tin		7440-31-5	unspecified
Pretreatment	Bleaching,optical brightenning	Potassium dichromate		7778-50-9	Cotton/Polyacrylic/Polyamid/Polyester/Silk
Coloring	Oxidizing / Reducing agent	Copper(II)acetate		142-71-2	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Oxidizing / Reducing agent	Copper(II) nitrate		3251-23-8	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Oxidizing / Reducing agent	Tin(IV) chloride		7646-78-8	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Oxidizing / Reducing agent	Tin(II) chloride		7772-99-8	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Carriers	Diphenyl oxide		101-84-8	Polyester
	Carriers	Propylbenzene		103-65-1	Polyester
	Carriers	1,4-Dichlorobenzene		106-46-7	Polyester

	Carriers	Chlorobenzene		108-90-7	Polyester
	Carriers	1,3-Dichlorotoluene		118-69-4	Polyester
	Carriers	2-hydroxy-benzoic acid, methyl ester		119-36-8	Polyester
	Carriers	1,2,3,4-Tetrahydronaphthalene		119-64-2	Polyester
	Carriers	Benzyl benzoate		120-51-4	Polyester
	Carriers	Dimethyl terephthalate		120-61-6	Polyester
	Carriers	1,2,4-Trichlorobenzene		120-82-1	Polyester
	Carriers	Dimethyl phthalate	DMP	131-11-3	Polyester
	Carriers	PCB		1336-36-3	Polyester
	Carriers	Butyl benzoate		136-60-7	Polyester
	Carriers	2-(4-chlorophenoxy)-ethanol		1892-43-9	Polyester
	Carriers	2-hydroxy-3-methyl-benzoic acid, methyl ester		23287-26-5	Polyester
	Carriers	2,2',4,4'-tetrachloro-1,1'-biphenyl		2437-79-8	Polyester
	Carriers	Ethyl phenoxyacetate		2555-49-9	Polyester
	Carriers	methyl-1,1'-biphenyl		28652-72-4	Polyester
	Carriers	Dimethylnaphthalene		28804-88-8	Polyester
	Carriers	(2,4-dichlorophenoxy)-acetic acid, ethyl ester		533-23-3	Polyester
	Carriers	1,3-Dichlorobenzene		541-73-1	Polyester
	Carriers	Diethyl phthalate	DEP	84-66-2	Polyester
	Carriers	1,2,3-Trichlorobenzene		87-61-6	Polyester
	Carriers	Pentachlorophenol	PCP	87-86-5	Polyester
	Carriers	1-Methylnaphthalene		90-12-0	Polyester
	Carriers	1-Chloronaphthalene		90-13-1	Polyester
	Carriers	o-Phenylphenol		90-43-7	Polyester
	Carriers	Naphthalene		91-20-3	Polyester
	Carriers	2-Methylnaphthalene		91-57-6	Polyester

	Carriers	Biphenyl		92-52-4	Polyester
	Carriers	p-Phenylphenol		92-69-3	Polyester
	Carriers	Methyl benzoate		93-58-3	Polyester
	Carriers	2-ethyl-naphthalene		939-27-5	Polyester
	Carriers	o-Chlorotoluene		95-49-8	Polyester
	Carriers	1,2-Dichlorobenzene		95-50-1	Polyester
	Carriers	1,2,4-Trimethylbenzene		95-63-6	Polyester
	Carriers	2,4-Dichlorotoluene		95-73-8	Polyester
	Carriers	3,4-Dichlorotoluene		95-75-0	Polyester
	Carriers	Benzal chloride		98-87-3	Polyester
	Fixing agent	Diethylene glycol		111-46-6	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Fixing agent	Di(Ethylhexyl) phthalate	DEHP	117-81-7	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Fixing agent	Zinc sulfoxylate-formaldehyde		24887-06-7	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Fixing agent	1,2,4-Butanetriol		3068-00-6	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Fixing agent	Butyl benzyl phthalate	BBP	85-68-7	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Fixing agent	N-Vinylpyrrolidinone		88-12-0	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Fixing agent	Dimethylformamide		1968-12-2	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Fixing agent	Chromium compounds		7440-47-3	Cotton/Polyacrylic/Polyamid/Polyester/Silk
Finishing	Softening treatment-Plasticizer	Poly(acrylamide)		9003-05-8	Cotton/Wool

	Softening treatment-Plasticizer	Oleic acid		112-80-1	Cotton/Wool
	Softening treatment-Plasticizer	Di(Ethylhexyl) phthalate	DEHP	117-81-7	Cotton/Wool
	Softening treatment-Plasticizer	Pentachlorobiphenyl		25429-29-2	Cotton/Wool
	Softening treatment-Plasticizer	Methylolstearamide		3370-35-2	Cotton/Wool
	Softening treatment-Plasticizer	1-octadecyl-2-imidazolidinone		4991-32-6	Cotton/Wool
	Softening treatment-Plasticizer	Silicon		7440-21-3	Cotton/Wool
	Softening treatment-Plasticizer	Dibutyl phthalate	DBP	84-74-2	Cotton/Wool
	Softening treatment-Plasticizer	polyvinyl chloride		9002-86-2	Cotton/Wool
	Softening treatment-Plasticizer	Polychlorinated biphenyls	PCB	1336-36-3	Cotton/Wool
	Softening treatment-Surface modifying	Stearic acid		57-11-4	Cotton/Wool
	Softening treatment-Surface modifying	Carboxymethyl cellulose		9000-11-7	Cotton/Wool
	Softening treatment-Surface modifying	Calcium chloride		10043-52-4	Cotton/Wool
	Softening treatment-Surface modifying	Kaolin		1332-58-7	Cotton/Wool
	Softening treatment-Surface modifying	Talc		14807-96-6	Cotton/Wool
	Softening treatment-Surface	Calcium carbonate		471-34-1	Cotton/Wool

	modifying				
	Softening treatment-Surface modifying	Glycerin		56-81-5	Cotton/Wool
	Softening treatment-Surface modifying	Sucrose		57-50-1	Cotton/Wool
	Softening treatment-Surface modifying	Sodium metasilicate		6834-92-0	Cotton/Wool
	Softening treatment-Surface modifying	Zinc chloride		7646-85-7	Cotton/Wool
	Softening treatment-Surface modifying	Barium sulphate		7727-43-7	Cotton/Wool
	Softening treatment-Surface modifying	Paraffin wax		8002-74-2	Cotton/Wool
	Softening treatment-Surface modifying	Casein		9000-71-9	Cotton/Wool
	Softening treatment-Surface modifying	polyethylene		9002-88-4	Cotton/Wool
	Softening treatment-Surface modifying	Acetic acid ethenylester, homopolymer		9003-20-7	Cotton/Wool
	Softening treatment-Surface modifying	polystyrene		9003-53-6	Cotton/Wool
	Softening treatment-Surface modifying	Dextrin		9004-53-9	Cotton/Wool
	Softening treatment-Surface modifying	Ethyl cellulose		9004-57-3	Cotton/Wool
	Softening treatment-Surface modifying	Methyl cellulose		9004-67-5	Cotton/Wool
	Softening treatment-Surface modifying	Starch		9005-25-8	Cotton/Wool

	Antiwrinkle agent	2-Amino-2-methylpropanol hydrochloride		3207-12-3	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	Melamine-formaldehyde copolymer		9003-08-1	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	Urea, polymer with formaldehyde		9011-05-6	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	Glyoxal		107-22-2	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	Melamin		108-78-1	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	Di(hydroxyethyl)amine		114-42-2	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	Dimethylolethyltriazone		134-97-4	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	Dimethylolethyleneurea		136-84-5	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	Tetrahydro-1,3-bis(hydroxymethyl)-4-methoxy-5,5-dimethyl-2(1H)-pyrimidinone		13747-12-1	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	Zinc tetrafluoroborate		13826-88-5	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	N,N'-bis(hydroxymethyl)-urea		140-95-4	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	Dimethyloldihydroxy ethylene urea		1854-26-8	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	Dimethylolpropyleneurea		3270-74-4	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	4,5-Dihydroxytetrahydroimidazol-2-one		3720-97-6	Cotton/Polyacrylic/Polyamid/Polyester/Silk

	Antiwrinkle agent	Bis(hydroxymethyl)-carbamic acid, ethyl ester		3883-23-6	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	Dimethylol methyl carbamate		4913-31-9	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	Formaldehyde		50-00-0	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	Tetramethylol acetylenediurea		5395-50-6	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	Urea		57-13-6	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	Poly(dimethylsiloxane)		63148-62-9	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	Propylene urea		6531-31-3	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	3,5-Dimethyloluron		7327-69-7	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	Zinc chloride		7646-85-7	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	Zinc nitrate		7779-88-6	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	Magnesium chloride		7786-30-3	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Antiwrinkle agent	N-Methylolacrylamide		924-42-5	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Impregnating agent(repellent)	Acrylic acid		79-10-7	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Impregnating agent(repellent)	Melamine-formaldehyde copolymer		9003-08-1	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Impregnating	Aluminium acetate		139-12-8	Cotton/Polyacrylic/Polyamid/Po

	agent(repellent)				lyester/Silk
	Impregnating agent(repellent)	Ethyl acrylate		140-88-5	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Impregnating agent(repellent)	Methylolstearamide		3370-35-2	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Impregnating agent(repellent)	1-[[(1-oxooctadecyl)amino]methyl]-pyridinium chloride		4261-72-7	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Impregnating agent(repellent)	1-octadecyl-2-imidazolidinone		4991-32-6	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Impregnating agent(repellent)	Aluminumtriformate		7360-53-4	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Impregnating agent(repellent)	Silicon		7440-21-3	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Impregnating agent(repellent)	Paraffin wax		8002-74-2	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Impregnating agent(repellent)	1-[(C16-18-alkyloxy)methyl]-pyridinium chloride		85507-99-9	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Impregnating agent(repellent)	polyvinyl chloride		9002-86-2	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Impregnating agent(repellent)	Acetic acid ethenylester, homopolymer		9003-20-7	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Impregnating agent(repellent)	Aluminium triacetate		8006-13-1	Cotton/Polyacrylic/Polyamid/Polyester/Silk
	Flame retardants	Trimethylolmelamine		1017-56-7	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Flame retardants	Triethanolamine		102-71-6	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Flame retardants	Tris(2-chloroethyl) phosphate	TCEP	115-96-8	Cotton/Polyacrylic/Polyamid/Polyester/Wool

	Flame retardants	Decabromodiphenyl oxide	DeBDE	1163-19-5	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Flame retardants	Tetrakis(hydroxymethyl)phosphonium chloride		124-64-1	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Flame retardants	Tris(2,3-dibromopropyl) phosphate		126-72-7	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Flame retardants	Antimony trioxide		1309-64-4	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Flame retardants	Tungsten oxide		1314-35-8	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Flame retardants	Tris(1,3-dichloro-2-propyl)phosphate		13674-87-8	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Flame retardants	Tetrabromophthalic acid		13810-83-8	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Flame retardants	Potassium hexafluorotitanate		16919-27-0	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Flame retardants	Dipotassium hexafluorozirconate		16923-95-8	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Flame retardants	Tetrakis(hydroxymethyl)-phosphonium phosphate		22031-17-0	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Flame retardants	Hexabromocyclododecane	HBCDD	25637-99-4	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Flame retardants	Tris(chloropropyl)phosphate		13674-84-5	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Flame retardants	Pentabromodiphenylether	PeBDE	32534-81-9	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Flame retardants	Tetrakis(hydroxymethyl)phosphonium hydroxide		512-82-3	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Flame retardants	bis[tetrakis(hydroxymethyl)phospho		52221-67-7	Cotton/Polyacrylic/Polyamid/Po

		nium] oxalate			lyester/Wool
	Flame retardants	Tris(1-aziridinyl)phosphine oxide		545-55-1	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Flame retardants	Tetrakis(hydroxymethyl)phosphonium sulfate		55566-30-8	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Flame retardants	Tetrachlorophthalic acid		632-58-6	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Flame retardants	Titanium tetrachloride		7550-45-0	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Flame retardants	Tetrakis(hydroxymethyl)-phosphonium acetate		7580-37-2	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Flame retardants	polyvinyl chloride		9002-86-2	Cotton/Polyacrylic/Polyamid/Polyester/Wool
	Anti moths and other insects	Chlorophenol		25167-80-0	Cotton/Silk/Wool
	Anti moths and other insects	Trichlorophenol		25167-82-2	Cotton/Silk/Wool
	Anti moths and other insects	Pentachlorophenol	PCP	87-86-5	Cotton/Silk/Wool
	Anti moths and other insects	Naphthalene		91-20-3	Wool
	Antimicrobial	Mercury compounds		7439-97-6	Unspecified
	Antimicrobial	Copper compounds		7440-50-8	Unspecified
	Antimicrobial	Tin compounds		7440-31-5	Unspecified
	Antimicrobial	Zinc compounds		7440-66-6	Unspecified
Multipurpose auxiliaries	Washing and chemical additives in formulations	Nonylphenoxypoly(ethyleneoxy)ethanol		9016-45-9	Unspecified
	Solvents	2,4-dimethyl phenol		108-95-2	Unspecified
	Solvents	Phenol		108-95-2	Unspecified
	Solvents	Hexachloro-3-butadiene		87-68-3	Unspecified
	Solvents	Nitrophenol		100-02-7	Unspecified

	Solvents	4-Chloro-3-methylphenol		59-50-7	Unspecified
	Solvents	Toluene		108-88-3	Unspecified
	Solvents	Xylene		1330-20-7	Unspecified

Appendix 4. Ready-to-use data collected from previous studies

Table 15. The expected concentration of some typical chemicals in textiles (Lacasse and Baumann, 2004, p 622)

Substance or substance group		**Concentration on textile**	**Remarks**
Heavy metals	Mercury	0.01 ppm	
	Copper	1-50 ppm	
	Zinc	1-50 ppm	
	Cadmium	Few ppm	Small quantities can also occur as natural impurities in cellulose used for e.g. viscose fiber.
Biocide	Pentachlorophenol	5 ppm	Occasionally >100 ppm
Dyes		0.05-3%	
Carriers		0.1-1%	
Formaldehyde		<30-100 ppm	
Arylamines (azo cleavage)		<30 ppm	Limited occurrence in textiles
Flame retardants		1-10%	Limited occurrence in textiles
Fluorocarbons		0.3%	Limited occurrence in textiles

Table 16. Maximal concentration of some substances in pure PET fabrics from the 2003 DEPA survey

Substances	**Concentration in textile (ppm)**
Ba	1.7
Co	21.34
Cr	0.43
Pb	1.6
Sb	215
Nicotine	0.19
DEHP	2.6
fatty acids and CxHy (C20-40)	Detected

Appendix 5. Newly added textile chemicals for polyester and polyamide datasheets

These are the chemicals added to the initial qualitative datasheet when doing case studies of polyester and polyamide.

Table 17 Newly added possible residual chemicals in PES and PA

Substance	**CAS no.**	**Functions**	**Materials**	**Sources**
Titanium dioxide	13463-67-7	Fillers	PES, PA	Sattler and Schweizer, 2011; Anton and Baird., 2005
Antimony	7440-36-0	Impurities	PES	Jaffe and East, 2006
Caprolactam	105-60-2	Oligomers	PA	Lacasse and Baumann, 2004, p73
Poly(ethylene glycole)s	260402-71-0	Antistatic agents	PES, PA	Lacasse and Baumann, 2004,p444
Ethoxylated amines	61791-26-2	Antistatic agents	PES, PA	Lacasse and Baumann, 2004,p444
Ammonium salts	61789-90-8	Antistatic agents	PES, PA	Lacasse and Baumann, 2004,p444
Antistatic agent for nylon	260402-75-3	Antistatic agents	PA	Lacasse and Baumann, 2004,p444
Dihydroxyethyl sulfone	2580-77-0	Antistatic agents	PES, PA	Walp, 2000
Diethylenetriamine	111-40-0	Antistatic agents	PES, PA	Walp, 2000
Hexamethylenediamine	124-09-4	Antistatic agents	PES, PA	Walp, 2000
Lithium chloride	7447-41-8	Antistatic agents	PES, PA	Walp, 2000
C.I. Fluorescent Brightener 199	58449-88-0	Brighteners	PES	OEKOpro, 2011
C.I. Fluorescent Brightener 199(regioisomer: p-cyano)	13001-40-6	Brighteners	PES	OEKOpro, 2011
C.I. Fluorescent Brightener 191	12270-53-0	Brighteners	PA	OEKOpro, 2011
C.I. Fluorescent Brightener 351	54351-85-8	Brighteners	PA	OEKOpro, 2011

Appendix 6. The average chemical content in Polyester textiles

Table 18 shows the final results for PES textiles. In this table, concentration of each chemical substance is indicated in percentage by weight of the textile substrate. Red marked substances are those restricted and their average content is estimated to be equal to the detection limits.

Table 18 Final results for PES textiles

Processes	**Functions**	**Substances**	**Trade name**	**CAS**	**Content**
Fiber Production	Fillers	Titanium dioxide		13463-67-7	2%
	Impurities	Lead		7439-92-1	0.5 ppm
	Impurities	Cadmium		7440-43-9	0.5 ppm
	Impurities	Tin		7440-31-5	0.5 ppm
	Impurities	Antimony		7440-36-0	0.20%
Pretreatment	Brightener	C.I. Fluorescent Brightener 199		58449-88-0	0.35%
	Brightener	C.I. Fluorescent Brightener 199 (regioisomer: p-cyano)		13001-40-6	0.35%
Coloring	Carriers	Diphenyl oxide		101-84-8	0.06%
	Carriers	Propylbenzene		103-65-1	0.06%
	Carriers	1,4-Dichlorobenzene		106-46-7	0.06%
	Carriers	Chlorobenzene		108-90-7	0.06%
	Carriers	1,3-Dichlorotoluene		118-69-4	0.06%
	Carriers	2-hydroxy-benzoic acid, methyl ester		119-36-8	0.06%
	Carriers	1,2,3,4-Tetrahydronaphthalene		119-64-2	0.06%
	Carriers	Benzyl benzoate		120-51-4	0.06%
	Carriers	Dimethyl terephthalate		120-61-6	0.06%
	Carriers	1,2,4-Trichlorobenzene		120-82-1	0.06%

	Carriers	Dimethyl phthalate	DMP	131-11-3	0.06%
	Carriers	PCB		1336-36-3	0.06%
	Carriers	Butyl benzoate		136-60-7	0.06%
	Carriers	2-(4-chlorophenoxy)-ethanol		1892-43-9	0.06%
	Carriers	2-hydroxy-3-methyl-benzoic acid, methyl ester		23287-26-5	0.06%
	Carriers	2,2',4,4'-tetrachloro-1,1'-biphenyl		2437-79-8	0.06%
	Carriers	Ethyl phenoxyacetate		2555-49-9	0.06%
	Carriers	methyl-1,1'-biphenyl		28652-72-4	0.06%
	Carriers	Dimethylnaphthalene		28804-88-8	0.06%
	Carriers	(2,4-dichlorophenoxy)-acetic acid, ethyl ester		533-23-3	0.06%
	Carriers	1,3-Dichlorobenzene		541-73-1	0.06%
	Carriers	Diethyl phthalate	DEP	84-66-2	0.06%
	Carriers	1,2,3-Trichlorobenzene		87-61-6	0.06%
	Carriers	Pentachlorophenol	PCP	87-86-5	0.5ppm
	Carriers	1-Methylnaphthalene		90-12-0	0.06%
	Carriers	1-Chloronaphthalene		90-13-1	0.06%
	Carriers	o-Phenylphenol		90-43-7	0.06%
	Carriers	Naphthalene		91-20-3	0.06%
	Carriers	2-Methylnaphthalene		91-57-6	0.06%
	Carriers	Biphenyl		92-52-4	0.06%
	Carriers	p-Phenylphenol		92-69-3	0.06%
	Carriers	Methyl benzoate		93-58-3	0.06%
	Carriers	2-ethyl-naphthalene		939-27-5	0.06%
	Carriers	o-Chlorotoluene		95-49-8	0.06%
	Carriers	1,2-Dichlorobenzene		95-50-1	0.06%
	Carriers	1,2,4-Trimethylbenzene		95-63-6	0.06%
	Carriers	2,4-Dichlorotoluene		95-73-8	0.06%
	Carriers	3,4-Dichlorotoluene		95-75-0	0.06%

	Carriers	Benzal chloride		98-87-3	0.06%
	Fixing agent	Diethylene glycol		111-46-6	0.35%
	Fixing agent	Zinc sulfoxylate-formaldehyde		24887-06-7	0.35%
	Fixing agent	1,2,4-Butanetriol		3068-00-6	0.35%
	Fixing agent	N-Vinyl-2-pyrrolidone		88-12-0	0.35%
	Fixing agent	Dimethyl formamide		68-12-2	0.35%
	Fixing agent	Chromium compounds		7440-47-3	3ppm
	Dyestuffs	C.I. 11280		6364-35-8	0.013%
	Dyestuffs	C.I. 24230		6655-96-5	0.013%
	Dyestuffs	C.I. 37270		91-59-8	0.003%
	Dyestuffs	C.I. Acid Black 131		12219-01-1	0.012%
	Dyestuffs	C.I. Acid Black 132		12219-02-2	0.012%
	Dyestuffs	C.I. Acid Black 209		72827-68-0	0.012%
	Dyestuffs	C.I. Acid Black 28		5850-41-9	0.012%
	Dyestuffs	C.I. Acid Black 29		12217-14-0	0.012%
	Dyestuffs	C.I. Acid Black 66		6360-59-4	0.012%
	Dyestuffs	C.I. Acid Black 70		8005-88-7	0.012%
	Dyestuffs	C.I. Acid Black 94		6358-80-1	0.012%
	Dyestuffs	C.I. Acid Brown 415		85828-74-6	0.012%
	Dyestuffs	C.I. Acid Orange 16		33340-36-2	0.012%
	Dyestuffs	C.I. Acid Orange 31		5858-89-9	0.012%
	Dyestuffs	C.I. Acid Orange 45		2429-80-3	0.012%
	Dyestuffs	C.I. Acid Red 107		6416-33-7	0.012%
	Dyestuffs	C.I. Acid Red 114		6459-94-5	0.012%
	Dyestuffs	C.I. Acid Red 115		6226-80-8	0.012%
	Dyestuffs	C.I. Acid Red 128		6548-30-7	0.012%
	Dyestuffs	C.I. Acid Red 148		6300-53-4	0.012%
	Dyestuffs	C.I. Acid Red 150		6226-78-4	0.012%

	Dyestuffs	C.I. Acid Red 158		8004-55-5	0.012%
	Dyestuffs	C.I. Acid Red 167		61901-41-5	0.012%
	Dyestuffs	C.I. Acid Red 22		5864-85-7	0.012%
	Dyestuffs	C.I. Acid Red 264		6505-96-0	0.012%
	Dyestuffs	C.I. Acid Red 265		6358-43-6	0.012%
	Dyestuffs	C.I. Acid Red 323		6358-34-5	0.012%
	Dyestuffs	C.I. Acid Red 35		6441-93-6	0.012%
	Dyestuffs	C.I. Acid Red 350		61827-80-3	0.012%
	Dyestuffs	C.I. Acid Red 4		5858-39-9	0.012%
	Dyestuffs	C.I. Acid Red 5		5858-63-9	0.012%
	Dyestuffs	C.I. Acid Red 73		5413-75-2	0.012%
	Dyestuffs	C.I. Acid Red 85		3567-65-5	0.012%
	Dyestuffs	C.I. Acid Violet 12		6625-46-3	0.012%
	Dyestuffs	C.I. Azoic Brown 29		95-53-4	0.003%
	Dyestuffs	C.I. Azoic Diazo Component 11		3165-93-3	0.011%
	Dyestuffs	C.I. Azoic Diazo Component 112		92-87-5	0.003%
	Dyestuffs	C.I. Azoic Diazo Component 113		119-93-7	0.003%
	Dyestuffs	C.I. Azoic Diazo Component 12		99-55-8	0.003%
	Dyestuffs	C.I. Azoic Diazo Component 4		2298-13-7	0.011%
	Dyestuffs	C.I. Azoic Diazo Component 41		27761-27-9	0.011%
	Dyestuffs	C.I. Azoic Diazo Component 48		20282-70-6	0.011%
	Dyestuffs	C.I. Basic Brown 2		6358-83-4	0.013%
	Dyestuffs	C.I. Basic Brown 4		5421-66-9	0.013%
	Dyestuffs	C.I. Basic Red 111		113741-92-7	0.013%
	Dyestuffs	C.I. Basic Red 76		68391-30-0	0.013%
	Dyestuffs	C.I. Direct Black 100		6358-73-2	0.011%
	Dyestuffs	C.I. Direct Black 11		6486-52-8	0.011%
	Dyestuffs	C.I. Direct Black 131		6486-54-0	0.011%

	Dyestuffs	C.I. Direct Black 14		4656-30-8	0.011%
	Dyestuffs	C.I. Direct Black 15		6426-75-1	0.011%
	Dyestuffs	C.I. Direct Black 154		37372-50-2	0.011%
	Dyestuffs	C.I. Direct Black 27		6360-39-0	0.011%
	Dyestuffs	C.I. Direct Black 29		3626-23-1	0.011%
	Dyestuffs	C.I. Direct Black 34		6473-08-1	0.011%
	Dyestuffs	C.I. Direct Black 38		1937-37-7	0.011%
	Dyestuffs	C.I. Direct Black 4		2429-83-6	0.011%
	Dyestuffs	C.I. Direct Black 40		6449-81-6	0.011%
	Dyestuffs	C.I. Direct Black 41		6486-53-9	0.011%
	Dyestuffs	C.I. Direct Black 83		6837-80-5	0.011%
	Dyestuffs	C.I. Direct Black 87		119-90-4	0.003%
	Dyestuffs	C.I. Direct Blue 1		2610-05-1	0.011%
	Dyestuffs	C.I. Direct Blue 10		4198-19-0	0.011%
	Dyestuffs	C.I. Direct Blue 11		6451-04-3	0.011%
	Dyestuffs	C.I. Direct Blue 131		6661-39-8	0.011%
	Dyestuffs	C.I. Direct Blue 14		72-57-1	0.011%
	Dyestuffs	C.I. Direct Blue 15		2429-74-5	0.011%
	Dyestuffs	C.I. Direct Blue 151		6449-35-0	0.011%
	Dyestuffs	C.I. Direct Blue 16		6426-66-0	0.011%
	Dyestuffs	C.I. Direct Blue 160		83221-79-8	0.011%
	Dyestuffs	C.I. Direct Blue 177		6426-76-2	0.011%
	Dyestuffs	C.I. Direct Blue 19		6426-68-2	0.011%
	Dyestuffs	C.I. Direct Blue 192		159202-76-3	0.011%
	Dyestuffs	C.I. Direct Blue 2		2429-73-4	0.011%
	Dyestuffs	C.I. Direct Blue 201		60800-55-7	0.011%
	Dyestuffs	C.I. Direct Blue 21		6420-09-3	0.011%
	Dyestuffs	C.I. Direct Blue 215		6771-80-8	0.011%

	Dyestuffs	C.I. Direct Blue 22		2586-57-4	0.011%
	Dyestuffs	C.I. Direct Blue 230		6527-65-7	0.011%
	Dyestuffs	C.I. Direct Blue 25		2150-54-1	0.011%
	Dyestuffs	C.I. Direct Blue 26		7082-31-7	0.011%
	Dyestuffs	C.I. Direct Blue 295		6420-22-0	0.011%
	Dyestuffs	C.I. Direct Blue 3		2429-72-3	0.011%
	Dyestuffs	C.I. Direct Blue 31		5442-09-1	0.011%
	Dyestuffs	C.I. Direct Blue 35		6473-33-2	0.011%
	Dyestuffs	C.I. Direct Blue 38		1324-83-0	0.011%
	Dyestuffs	C.I. Direct Blue 42		6426-71-7	0.011%
	Dyestuffs	C.I. Direct Blue 43		7273-59-8	0.011%
	Dyestuffs	C.I. Direct Blue 48		6459-89-8	0.011%
	Dyestuffs	C.I. Direct Blue 49		6426-73-9	0.011%
	Dyestuffs	C.I. Direct Blue 51		6360-65-2	0.011%
	Dyestuffs	C.I. Direct Blue 53		314-13-6	0.011%
	Dyestuffs	C.I. Direct Blue 58		6426-69-3	0.011%
	Dyestuffs	C.I. Direct Blue 6		2602-46-2	0.011%
	Dyestuffs	C.I. Direct Blue 64		6426-74-0	0.011%
	Dyestuffs	C.I. Direct Blue 8		2429-71-2	0.011%
	Dyestuffs	C.I. Direct Brown 1		3811-71-0	0.011%
	Dyestuffs	C.I. Direct Brown 1:2		2586-58-5	0.011%
	Dyestuffs	C.I. Direct Brown 101		8626-29-7	0.011%
	Dyestuffs	C.I. Direct Brown 13		8003-82-5	0.011%
	Dyestuffs	C.I. Direct Brown 14		8002-97-9	0.011%
	Dyestuffs	C.I. Direct Brown 151		10130-38-8	0.011%
	Dyestuffs	C.I. Direct Brown 154		6360-54-9	0.011%
	Dyestuffs	C.I. Direct Brown 159		10214-11-6	0.011%
	Dyestuffs	C.I. Direct Brown 17		6661-48-9	0.011%

	Dyestuffs	C.I. Direct Brown 173		6826-64-8	0.011%
	Dyestuffs	C.I. Direct Brown 175		6528-58-1	0.011%
	Dyestuffs	C.I. Direct Brown 2		2429-82-5	0.011%
	Dyestuffs	C.I. Direct Brown 20		1324-67-0	0.011%
	Dyestuffs	C.I. Direct Brown 21		6442-05-3	0.011%
	Dyestuffs	C.I. Direct Brown 215		83606-72-8	0.011%
	Dyestuffs	C.I. Direct Brown 222		64743-15-3	0.011%
	Dyestuffs	C.I. Direct Brown 24		8003-74-5	0.011%
	Dyestuffs	C.I. Direct Brown 25		33363-87-0	0.011%
	Dyestuffs	C.I. Direct Brown 26		8003-55-2	0.011%
	Dyestuffs	C.I. Direct Brown 27		6360-29-8	0.011%
	Dyestuffs	C.I. Direct Brown 31		2429-81-4	0.011%
	Dyestuffs	C.I. Direct Brown 33		1324-87-4	0.011%
	Dyestuffs	C.I. Direct Brown 39		6473-06-9	0.011%
	Dyestuffs	C.I. Direct Brown 43		6471-44-9	0.011%
	Dyestuffs	C.I. Direct Brown 46		8003-51-8	0.011%
	Dyestuffs	C.I. Direct Brown 5		6844-77-5	0.011%
	Dyestuffs	C.I. Direct Brown 51		4623-91-0	0.011%
	Dyestuffs	C.I. Direct Brown 52		6505-12-0	0.011%
	Dyestuffs	C.I. Direct Brown 54		8003-50-7	0.011%
	Dyestuffs	C.I. Direct Brown 56		6486-31-3	0.011%
	Dyestuffs	C.I. Direct Brown 57		6360-28-7	0.011%
	Dyestuffs	C.I. Direct Brown 58		6426-59-1	0.011%
	Dyestuffs	C.I. Direct Brown 59		3476-90-2	0.011%
	Dyestuffs	C.I. Direct Brown 6		2893-80-3	0.011%
	Dyestuffs	C.I. Direct Brown 60		6426-57-9	0.011%
	Dyestuffs	C.I. Direct Brown 61		6505-33-5	0.011%
	Dyestuffs	C.I. Direct Brown 62		8003-56-3	0.011%

	Dyestuffs	C.I. Direct Brown 68		6449-85-0	0.011%
	Dyestuffs	C.I. Direct Brown 7		6837-86-1	0.011%
	Dyestuffs	C.I. Direct Brown 70		6428-42-8	0.011%
	Dyestuffs	C.I. Direct Brown 73		6428-43-9	0.011%
	Dyestuffs	C.I. Direct Brown 74		8014-91-3	0.011%
	Dyestuffs	C.I. Direct Brown 75		1324-84-1	0.011%
	Dyestuffs	C.I. Direct Brown 79		6483-77-8	0.011%
	Dyestuffs	C.I. Direct Brown 86		6486-30-2	0.011%
	Dyestuffs	C.I. Direct Brown 95		16071-86-6	0.011%
	Dyestuffs	C.I. Direct Green 1		3626-28-6	0.011%
	Dyestuffs	C.I. Direct Green 10		6360-61-8	0.011%
	Dyestuffs	C.I. Direct Green 12		6486-55-1	0.011%
	Dyestuffs	C.I. Direct Green 19		6486-58-4	0.011%
	Dyestuffs	C.I. Direct Green 21		8003-52-9	0.011%
	Dyestuffs	C.I. Direct Green 22		6860-33-4	0.011%
	Dyestuffs	C.I. Direct Green 39		6360-57-2	0.011%
	Dyestuffs	C.I. Direct Green 58		110735-26-7	0.011%
	Dyestuffs	C.I. Direct Green 6		4335-09-5	0.011%
	Dyestuffs	C.I. Direct Green 60		6426-56-8	0.011%
	Dyestuffs	C.I. Direct Green 7		6360-64-1	0.011%
	Dyestuffs	C.I. Direct Green 8		5422-17-3	0.011%
	Dyestuffs	C.I. Direct Green 85		72390-60-4	0.011%
	Dyestuffs	C.I. Direct Green 9		6360-62-9	0.011%
	Dyestuffs	C.I. Direct Orange 1		6459-87-6	0.011%
	Dyestuffs	C.I. Direct Orange 10		6405-94-3	0.011%
	Dyestuffs	C.I. Direct Orange 13		6486-43-7	0.011%
	Dyestuffs	C.I. Direct Orange 2		8005-97-8	0.011%
	Dyestuffs	C.I. Direct Orange 30		6420-04-8	0.011%

	Dyestuffs	C.I. Direct Orange 31		6420-03-7	0.011%
	Dyestuffs	C.I. Direct Orange 33		13190-99-3	0.011%
	Dyestuffs	C.I. Direct Orange 6		6637-88-3	0.011%
	Dyestuffs	C.I. Direct Orange 7		2868-76-0	0.011%
	Dyestuffs	C.I. Direct Orange 8		2429-79-0	0.011%
	Dyestuffs	C.I. Direct Red 1		2429-84-7	0.011%
	Dyestuffs	C.I. Direct Red 10		2429-70-1	0.011%
	Dyestuffs	C.I. Direct Red 123		6470-23-1	0.011%
	Dyestuffs	C.I. Direct Red 13		1937-35-5	0.011%
	Dyestuffs	C.I. Direct Red 17		2769-07-5	0.011%
	Dyestuffs	C.I. Direct Red 18		6548-26-1	0.011%
	Dyestuffs	C.I. Direct Red 2		992-59-6	0.011%
	Dyestuffs	C.I. Direct Red 21		6406-01-5	0.011%
	Dyestuffs	C.I. Direct Red 24		6420-44-6	0.011%
	Dyestuffs	C.I. Direct Red 26		3687-80-7	0.011%
	Dyestuffs	C.I. Direct Red 28		573-58-0	0.011%
	Dyestuffs	C.I. Direct Red 29		6426-54-6	0.011%
	Dyestuffs	C.I. Direct Red 33		6253-15-2	0.011%
	Dyestuffs	C.I. Direct Red 37		3530-19-6	0.011%
	Dyestuffs	C.I. Direct Red 39		6358-29-8	0.011%
	Dyestuffs	C.I. Direct Red 42		6548-39-6	0.011%
	Dyestuffs	C.I. Direct Red 43		6486-50-6	0.011%
	Dyestuffs	C.I. Direct Red 44		2302-97-8	0.011%
	Dyestuffs	C.I. Direct Red 46		6548-29-4	0.011%
	Dyestuffs	C.I. Direct Red 52		6797-93-9	0.011%
	Dyestuffs	C.I. Direct Red 53		6375-58-2	0.011%
	Dyestuffs	C.I. Direct Red 59		6655-94-3	0.011%
	Dyestuffs	C.I. Direct Red 60		6486-49-3	0.011%

	Dyestuffs	C.I. Direct Red 61		6470-31-1	0.011%
	Dyestuffs	C.I. Direct Red 62		6420-43-5	0.011%
	Dyestuffs	C.I. Direct Red 67		6598-56-7	0.011%
	Dyestuffs	C.I. Direct Red 7		2868-75-9	0.011%
	Dyestuffs	C.I. Direct Red 72		8005-64-9	0.011%
	Dyestuffs	C.I. Direct Red 73		6460-01-1	0.011%
	Dyestuffs	C.I. Direct Red 74		8003-75-6	0.011%
	Dyestuffs	C.I. Direct Red 88		6459-86-5	0.011%
	Dyestuffs	C.I. Direct Violet 1		2586-60-9	0.011%
	Dyestuffs	C.I. Direct Violet 12		2429-75-6	0.011%
	Dyestuffs	C.I. Direct Violet 17		6426-65-9	0.011%
	Dyestuffs	C.I. Direct Violet 22		6426-67-1	0.011%
	Dyestuffs	C.I. Direct Violet 27		6426-64-8	0.011%
	Dyestuffs	C.I. Direct Violet 28		6420-06-0	0.011%
	Dyestuffs	C.I. Direct Violet 3		6507-83-1	0.011%
	Dyestuffs	C.I. Direct Violet 32		6428-94-0	0.011%
	Dyestuffs	C.I. Direct Violet 36		6472-94-2	0.011%
	Dyestuffs	C.I. Direct Violet 38		6426-77-3	0.011%
	Dyestuffs	C.I. Direct Violet 4		6472-95-3	0.011%
	Dyestuffs	C.I. Direct Violet 42		6459-88-7	0.011%
	Dyestuffs	C.I. Direct Violet 43		6426-63-7	0.011%
	Dyestuffs	C.I. Direct Violet 45		6426-72-8	0.011%
	Dyestuffs	C.I. Direct Violet 85		6507-84-2	0.011%
	Dyestuffs	C.I. Direct Yellow 1		6472-91-9	0.011%
	Dyestuffs	C.I. Direct Yellow 20		6426-62-6	0.011%
	Dyestuffs	C.I. Direct Yellow 24		6486-29-9	0.011%
	Dyestuffs	C.I. Disperse Blue 1		2475-45-8	0.010%
	Dyestuffs	C.I. Disperse Blue 106		12223-01-7	0.010%

	Dyestuffs	C.I. Disperse Blue 124		15141-18-1	0.010%
	Dyestuffs	C.I. Disperse Blue 3		2475-46-9	0.010%
	Dyestuffs	C.I. Disperse Blue 35		56524-77-7	0.010%
	Dyestuffs	C.I. Disperse Blue 7		3179-90-6	0.010%
	Dyestuffs	C.I. Disperse Orange 1		2581-69-3	0.010%
	Dyestuffs	C.I. Disperse Orange 149		85136-74-9	0.012%
	Dyestuffs	C.I. Disperse Orange 3		730-40-5	0.010%
	Dyestuffs	C.I. Disperse Orange 37		12223-33-5	0.010%
	Dyestuffs	C.I. Disperse Red 1		2872-52-8	0.010%
	Dyestuffs	C.I. Disperse Red 15		116-85-8	0.012%
	Dyestuffs	C.I. Disperse Red 17		3179-89-3	0.010%
	Dyestuffs	C.I. Disperse Red 220		65907-69-9	0.012%
	Dyestuffs	C.I. Disperse Yellow 1		119-15-3	0.010%
	Dyestuffs	C.I. Disperse Yellow 23		6250-23-3	0.012%
	Dyestuffs	C.I. Disperse Yellow 3		2832-40-8	0.010%
	Dyestuffs	C.I. Disperse Yellow 39		12236-29-2	0.010%
	Dyestuffs	C.I. Disperse Yellow 49		54824-37-2	0.010%
	Dyestuffs	C.I. Disperse Yellow 7		6300-37-4	0.012%
	Dyestuffs	C.I. Disperse Yellow 9		6373-73-5	0.010%
	Dyestuffs	C.I. Mordant Yellow 16		8003-87-0	0.013%
	Dyestuffs	C.I. Oxidation Base 35		95-80-7	0.003%
	Dyestuffs	Diazo Fast Blue BB		120-00-3	0.013%
Finishing	Antiwrinkle agent	2-Amino-2-methylpropanol hydrochloride		3207-12-3	0.01%
	Antiwrinkle agent	Melamine-formaldehyde copolymer		9003-08-1	0.01%
	Antiwrinkle agent	Urea, polymer with formaldehyde		9011-05-6	0.01%
	Antiwrinkle agent	Glyoxal		107-22-2	0.01%
	Antiwrinkle agent	Melamin		108-78-1	0.01%

	Antiwrinkle agent	Di(hydroxyethyl)amine		114-42-2	0.01%
	Antiwrinkle agent	Dimethylolethyltriazone		134-97-4	0.01%
	Antiwrinkle agent	Dimethylolethyleneurea		136-84-5	0.01%
	Antiwrinkle agent	Tetrahydro-1,3-bis(hydroxymethyl)-4-methoxy-5,5-dimethyl -2(1H)-pyrimidinone		13747-12-1	0.01%
	Antiwrinkle agent	Zinc tetrafluoroborate		13826-88-5	0.01%
	Antiwrinkle agent	N,N'-bis(hydroxymethyl)-urea		140-95-4	0.01%
	Antiwrinkle agent	Dimethyloldihydroxy ethylene urea		1854-26-8	0.01%
	Antiwrinkle agent	Dimethylolpropyleneurea		3270-74-4	0.01%
	Antiwrinkle agent	4,5-Dihydroxytetrahydroimidazol-2-one		3720-97-6	0.01%
	Antiwrinkle agent	Bis(hydroxymethyl)-carbamic acid, ethyl ester		3883-23-6	0.01%
	Antiwrinkle agent	Dimethylol methyl carbamate		4913-31-9	0.01%
	Antiwrinkle agent	Formaldehyde		50-00-0	0.01%
	Antiwrinkle agent	Tetramethylol acetylenediurea		5395-50-6	0.01%
	Antiwrinkle agent	Urea		57-13-6	0.01%
	Antiwrinkle agent	Poly(dimethylsiloxane)		63148-62-9	0.01%
	Antiwrinkle agent	Propylene urea		6531-31-3	0.01%
	Antiwrinkle agent	3,5-Dimethyloluron		7327-69-7	0.01%
	Antiwrinkle agent	Zinc chloride		7646-85-7	0.01%
	Antiwrinkle agent	Zinc nitrate		7779-88-6	0.01%
	Antiwrinkle agent	Magnesium chloride		7786-30-3	0.01%
	Antiwrinkle agent	N-Methylolacrylamide		924-42-5	0.01%
	Repellent	Acrylic acid		79-10-7	0.02%
	Repellent	Melamine-formaldehyde copolymer		9003-08-1	0.02%
	Repellent	Aluminium acetate		139-12-8	0.02%
	Repellent	Ethyl acrylate		140-88-5	0.02%
	Repellent	Methylolstearamide		3370-35-2	0.02%
	Repellent	1-[[(1-oxooctadecyl)amino]methyl]-pyridinium chloride		4261-72-7	0.02%

	Repellent	1-octadecyl-2-imidazolidinone		4991-32-6	0.02%
	Repellent	Aluminumformate		7360-53-4	0.02%
	Repellent	Silicon		7440-21-3	0.02%
	Repellent	Paraffin wax		8002-74-2	0.02%
	Repellent	1-[(C16-18-alkyloxy)methyl]-pyridinium chloride		85507-99-9	0.02%
	Repellent	Polyvinylchloride		9002-86-2	0.02%
	Repellent	Acetic acid ethenylester, homopolymer		9003-20-7	0.02%
	Repellent	Aluminium triacetate		8006-13-1	0.02%
	Flame retardants	Trimethylolmelamine		1017-56-7	0.04%
	Flame retardants	Triethanolamine		102-71-6	0.04%
	Flame retardants	Tris(2-chloroethyl) phosphate	TCEP	115-96-8	0.04%
	Flame retardants	Decabromodiphenyl oxide	DeBDE	1163-19-5	0.04%
	Flame retardants	Tetrakis(hydroxymethyl)phosphonium chloride		124-64-1	0.04%
	Flame retardants	Antimony trioxide		1309-64-4	0.04%
	Flame retardants	Tungsten oxide		1314-35-8	0.04%
	Flame retardants	Tris(1,3-dichloro-2-propyl)phosphate		13674-87-8	0.04%
	Flame retardants	Tetrabromophthalic acid		13810-83-8	0.04%
	Flame retardants	Potassium hexafluorotitanate		16919-27-0	0.04%
	Flame retardants	Dipotassium hexafluorozirconate		16923-95-8	0.04%
	Flame retardants	Tetrakis(hydroxymethyl)-phosphonium phosphate		22031-17-0	0.04%
	Flame retardants	Hexabromocyclododecane	HBCDD	25637-99-4	0.04%
	Flame retardants	Tris(chloropropyl)phosphate		13674-84-5	0.04%
	Flame retardants	Pentabromodiphenylether	PeBDE	32534-81-9	0.04%
	Flame retardants	Tetrakis(hydroxymethyl)phosphonium hydroxide		512-82-3	0.04%
	Flame retardants	Tetrakis(hydroxymethyl)phosphonium ethanedioate		52221-67-7	0.04%
	Flame retardants	Tris(1-aziridinyl)phosphine oxide		545-55-1	0.04%
	Flame retardants	Tetrakis(hydroxymethyl)phosphonium sulfate		55566-30-8	0.04%
	Flame retardants	Tetrachlorophthalic acid		632-58-6	0.04%

	Flame retardants	Titanium tetrachloride		7550-45-0	0.04%
	Flame retardants	Tetrakis(hydroxymethyl)-phosphonium acetate		7580-37-2	0.04%
	Flame retardants	Polyvinyl chloride		9002-86-2	0.04%
	Antimicrobial	Copper compounds		7440-50-8	0.08%
	Antimicrobial	Tin compounds		7440-31-5	0.08%
	Antimicrobial	Zinc compounds		7440-66-6	0.08%
	Antistatic	Poly(ethylene glycole)s		260402-71-0	0.04%
	Antistatic	Ethoxylated amines		61791-26-2	0.04%
	Antistatic	Ammonium salts		61789-90-8	0.04%
	Antistatic	Dihydroxyethyl sulfone		2580-77-0	0.04%
	Antistatic	Diethylenetriamine		111-40-0	0.04%
	Antistatic	Hexamethylenediamine		124-09-4	0.04%
	Antistatic	Lithium chloride		7447-41-8	0.04%
Multipurpose auxiliaries	Washing and chemical additives in formulations	Nonylphenoxypoly(ethyleneoxy)ethanol		9016-45-9	0.7 ppm
Polymer substrate		Poly(ethylene terephthalate)	PET	25038-59-9	88.48%

Appendix 7. The average chemical content in Polyamide textiles

Table 19 shows the final results for PES textiles. In this table, concentration of each chemical substance is indicated in percentage by weight of the textile substrate. Red marked substances are those restricted and their average content is estimated to be equal to the detection limits.

Table 19 Final results for PA textiles

Processes	**Functions**	**Substances**	**Trade name**	**CAS**	**Content**
Fiber Production	Oligomers	Caprolactam		105-60-2	1%
	Fillers	Titanium dioxide		13463-67-7	1%
	Impurities	Lead		7439-92-1	0.5 ppm
	Impurities	Cadmium		7440-43-9	0.5 ppm
	Impurities	Tin		7440-31-5	0.5 ppm
Pretreatment	Brightener	C.I. Fluorescent Brightener 191		12270-53-0	0.35%
	Brightener	C.I. Fluorescent Brightener 351		54351-85-8	0.35%
Coloring	Fixing agent	Diethylene glycol		111-46-6	0.38%
	Fixing agent	Zinc sulfoxylate-formaldehyde		24887-06-7	0.38%
	Fixing agent	1,2,4-Butanetriol		3068-00-6	0.38%
	Fixing agent	N-Vinyl-2-pyrrolidone		88-12-0	0.38%
	Fixing agent	Dimethyl formamide		68-12-2	0.38%
	Fixing agent	Chromium compounds		7440-47-3	3ppm
	Dyestuffs	C.I. 11280		6364-35-8	0.013%
	Dyestuffs	C.I. 24230		6655-96-5	0.013%
	Dyestuffs	C.I. 37270		91-59-8	0.003%
	Dyestuffs	C.I. Acid Black 131		12219-01-1	0.012%

	Dyestuffs	C.I. Acid Black 132		12219-02-2	0.012%
	Dyestuffs	C.I. Acid Black 209		72827-68-0	0.012%
	Dyestuffs	C.I. Acid Black 28		5850-41-9	0.012%
	Dyestuffs	C.I. Acid Black 29		12217-14-0	0.012%
	Dyestuffs	C.I. Acid Black 66		6360-59-4	0.012%
	Dyestuffs	C.I. Acid Black 70		8005-88-7	0.012%
	Dyestuffs	C.I. Acid Black 94		6358-80-1	0.012%
	Dyestuffs	C.I. Acid Blue 40		6424-85-7	0.012%
	Dyestuffs	C.I. Acid Brown 415		85828-74-6	0.012%
	Dyestuffs	C.I. Acid Orange 156		68555-86-2	0.012%
	Dyestuffs	C.I. Acid Orange 16		33340-36-2	0.012%
	Dyestuffs	C.I. Acid Orange 31		5858-89-9	0.012%
	Dyestuffs	C.I. Acid Orange 45		2429-80-3	0.012%
	Dyestuffs	C.I. Acid Red 107		6416-33-7	0.012%
	Dyestuffs	C.I. Acid Red 114		6459-94-5	0.012%
	Dyestuffs	C.I. Acid Red 115		6226-80-8	0.012%
	Dyestuffs	C.I. Acid Red 128		6548-30-7	0.012%
	Dyestuffs	C.I. Acid Red 148		6300-53-4	0.012%
	Dyestuffs	C.I. Acid Red 150		6226-78-4	0.012%
	Dyestuffs	C.I. Acid Red 158		8004-55-5	0.012%
	Dyestuffs	C.I. Acid Red 167		61901-41-5	0.012%
	Dyestuffs	C.I. Acid Red 22		5864-85-7	0.012%
	Dyestuffs	C.I. Acid Red 26		3761-53-3	0.012%
	Dyestuffs	C.I. Acid Red 264		6505-96-0	0.012%
	Dyestuffs	C.I. Acid Red 265		6358-43-6	0.012%
	Dyestuffs	C.I. Acid Red 323		6358-34-5	0.012%
	Dyestuffs	C.I. Acid Red 35		6441-93-6	0.012%
	Dyestuffs	C.I. Acid Red 350		61827-80-3	0.012%

	Dyestuffs	C.I. Acid Red 4		5858-39-9	0.012%
	Dyestuffs	C.I. Acid Red 5		5858-63-9	0.012%
	Dyestuffs	C.I. Acid Red 73		5413-75-2	0.012%
	Dyestuffs	C.I. Acid Red 85		3567-65-5	0.012%
	Dyestuffs	C.I. Acid Violet 12		6625-46-3	0.012%
	Dyestuffs	C.I. Acid Violet 17		4129-84-4	0.012%
	Dyestuffs	C.I. Acid Yellow 23		1934-21-0	0.012%
	Dyestuffs	C.I. Azoic Brown 29		95-53-4	0.003%
	Dyestuffs	C.I. Azoic Diazo Component 11		3165-93-3	0.011%
	Dyestuffs	C.I. Azoic Diazo Component 112		92-87-5	0.003%
	Dyestuffs	C.I. Azoic Diazo Component 113		119-93-7	0.003%
	Dyestuffs	C.I. Azoic Diazo Component 12		99-55-8	0.003%
	Dyestuffs	C.I. Azoic Diazo Component 4		2298-13-7	0.011%
	Dyestuffs	C.I. Azoic Diazo Component 41		27761-27-9	0.011%
	Dyestuffs	C.I. Azoic Diazo Component 48		20282-70-6	0.011%
	Dyestuffs	C.I. Basic Brown 2		6358-83-4	0.013%
	Dyestuffs	C.I. Basic Brown 4		5421-66-9	0.013%
	Dyestuffs	C.I. Basic Red 111		113741-92-7	0.013%
	Dyestuffs	C.I. Basic Red 76		68391-30-0	0.013%
	Dyestuffs	C.I. Direct Black 100		6358-73-2	0.012%
	Dyestuffs	C.I. Direct Black 11		6486-52-8	0.012%
	Dyestuffs	C.I. Direct Black 131		6486-54-0	0.012%
	Dyestuffs	C.I. Direct Black 14		4656-30-8	0.012%
	Dyestuffs	C.I. Direct Black 15		6426-75-1	0.012%
	Dyestuffs	C.I. Direct Black 154		37372-50-2	0.012%
	Dyestuffs	C.I. Direct Black 27		6360-39-0	0.012%
	Dyestuffs	C.I. Direct Black 29		3626-23-1	0.012%
	Dyestuffs	C.I. Direct Black 34		6473-08-1	0.012%

	Dyestuffs	C.I. Direct Black 38		1937-37-7	0.012%
	Dyestuffs	C.I. Direct Black 4		2429-83-6	0.012%
	Dyestuffs	C.I. Direct Black 40		6449-81-6	0.012%
	Dyestuffs	C.I. Direct Black 41		6486-53-9	0.012%
	Dyestuffs	C.I. Direct Black 83		6837-80-5	0.012%
	Dyestuffs	C.I. Direct Black 87		119-90-4	0.003%
	Dyestuffs	C.I. Direct Blue 1		2610-05-1	0.012%
	Dyestuffs	C.I. Direct Blue 10		4198-19-0	0.012%
	Dyestuffs	C.I. Direct Blue 11		6451-04-3	0.012%
	Dyestuffs	C.I. Direct Blue 131		6661-39-8	0.012%
	Dyestuffs	C.I. Direct Blue 14		72-57-1	0.012%
	Dyestuffs	C.I. Direct Blue 15		2429-74-5	0.012%
	Dyestuffs	C.I. Direct Blue 151		6449-35-0	0.012%
	Dyestuffs	C.I. Direct Blue 16		6426-66-0	0.012%
	Dyestuffs	C.I. Direct Blue 160		83221-79-8	0.012%
	Dyestuffs	C.I. Direct Blue 177		6426-76-2	0.012%
	Dyestuffs	C.I. Direct Blue 19		6426-68-2	0.012%
	Dyestuffs	C.I. Direct Blue 192		159202-76-3	0.012%
	Dyestuffs	C.I. Direct Blue 2		2429-73-4	0.012%
	Dyestuffs	C.I. Direct Blue 201		60800-55-7	0.012%
	Dyestuffs	C.I. Direct Blue 21		6420-09-3	0.012%
	Dyestuffs	C.I. Direct Blue 215		6771-80-8	0.012%
	Dyestuffs	C.I. Direct Blue 22		2586-57-4	0.012%
	Dyestuffs	C.I. Direct Blue 230		6527-65-7	0.012%
	Dyestuffs	C.I. Direct Blue 25		2150-54-1	0.012%
	Dyestuffs	C.I. Direct Blue 26		7082-31-7	0.012%
	Dyestuffs	C.I. Direct Blue 295		6420-22-0	0.012%
	Dyestuffs	C.I. Direct Blue 3		2429-72-3	0.012%

	Dyestuffs	C.I. Direct Blue 31		5442-09-1	0.012%
	Dyestuffs	C.I. Direct Blue 35		6473-33-2	0.012%
	Dyestuffs	C.I. Direct Blue 38		1324-83-0	0.012%
	Dyestuffs	C.I. Direct Blue 42		6426-71-7	0.012%
	Dyestuffs	C.I. Direct Blue 43		7273-59-8	0.012%
	Dyestuffs	C.I. Direct Blue 48		6459-89-8	0.012%
	Dyestuffs	C.I. Direct Blue 49		6426-73-9	0.012%
	Dyestuffs	C.I. Direct Blue 51		6360-65-2	0.012%
	Dyestuffs	C.I. Direct Blue 53		314-13-6	0.012%
	Dyestuffs	C.I. Direct Blue 58		6426-69-3	0.012%
	Dyestuffs	C.I. Direct Blue 6		2602-46-2	0.012%
	Dyestuffs	C.I. Direct Blue 64		6426-74-0	0.012%
	Dyestuffs	C.I. Direct Blue 8		2429-71-2	0.012%
	Dyestuffs	C.I. Direct Brown 1		3811-71-0	0.012%
	Dyestuffs	C.I. Direct Brown 1:2		2586-58-5	0.012%
	Dyestuffs	C.I. Direct Brown 101		8626-29-7	0.012%
	Dyestuffs	C.I. Direct Brown 13		8003-82-5	0.012%
	Dyestuffs	C.I. Direct Brown 14		8002-97-9	0.012%
	Dyestuffs	C.I. Direct Brown 151		10130-38-8	0.012%
	Dyestuffs	C.I. Direct Brown 154		6360-54-9	0.012%
	Dyestuffs	C.I. Direct Brown 159		10214-11-6	0.012%
	Dyestuffs	C.I. Direct Brown 17		6661-48-9	0.012%
	Dyestuffs	C.I. Direct Brown 173		6826-64-8	0.012%
	Dyestuffs	C.I. Direct Brown 175		6528-58-1	0.012%
	Dyestuffs	C.I. Direct Brown 2		2429-82-5	0.012%
	Dyestuffs	C.I. Direct Brown 20		1324-67-0	0.012%
	Dyestuffs	C.I. Direct Brown 21		6442-05-3	0.012%
	Dyestuffs	C.I. Direct Brown 215		83606-72-8	0.012%

	Dyestuffs	C.I. Direct Brown 222		64743-15-3	0.012%
	Dyestuffs	C.I. Direct Brown 24		8003-74-5	0.012%
	Dyestuffs	C.I. Direct Brown 25		33363-87-0	0.012%
	Dyestuffs	C.I. Direct Brown 26		8003-55-2	0.012%
	Dyestuffs	C.I. Direct Brown 27		6360-29-8	0.012%
	Dyestuffs	C.I. Direct Brown 31		2429-81-4	0.012%
	Dyestuffs	C.I. Direct Brown 33		1324-87-4	0.012%
	Dyestuffs	C.I. Direct Brown 39		6473-06-9	0.012%
	Dyestuffs	C.I. Direct Brown 43		6471-44-9	0.012%
	Dyestuffs	C.I. Direct Brown 46		8003-51-8	0.012%
	Dyestuffs	C.I. Direct Brown 5		6844-77-5	0.012%
	Dyestuffs	C.I. Direct Brown 51		4623-91-0	0.012%
	Dyestuffs	C.I. Direct Brown 52		6505-12-0	0.012%
	Dyestuffs	C.I. Direct Brown 54		8003-50-7	0.012%
	Dyestuffs	C.I. Direct Brown 56		6486-31-3	0.012%
	Dyestuffs	C.I. Direct Brown 57		6360-28-7	0.012%
	Dyestuffs	C.I. Direct Brown 58		6426-59-1	0.012%
	Dyestuffs	C.I. Direct Brown 59		3476-90-2	0.012%
	Dyestuffs	C.I. Direct Brown 6		2893-80-3	0.012%
	Dyestuffs	C.I. Direct Brown 60		6426-57-9	0.012%
	Dyestuffs	C.I. Direct Brown 61		6505-33-5	0.012%
	Dyestuffs	C.I. Direct Brown 62		8003-56-3	0.012%
	Dyestuffs	C.I. Direct Brown 68		6449-85-0	0.012%
	Dyestuffs	C.I. Direct Brown 7		6837-86-1	0.012%
	Dyestuffs	C.I. Direct Brown 70		6428-42-8	0.012%
	Dyestuffs	C.I. Direct Brown 73		6428-43-9	0.012%
	Dyestuffs	C.I. Direct Brown 74		8014-91-3	0.012%
	Dyestuffs	C.I. Direct Brown 75		1324-84-1	0.012%

	Dyestuffs	C.I. Direct Brown 79		6483-77-8	0.012%
	Dyestuffs	C.I. Direct Brown 86		6486-30-2	0.012%
	Dyestuffs	C.I. Direct Brown 95		16071-86-6	0.012%
	Dyestuffs	C.I. Direct Green 1		3626-28-6	0.012%
	Dyestuffs	C.I. Direct Green 10		6360-61-8	0.012%
	Dyestuffs	C.I. Direct Green 12		6486-55-1	0.012%
	Dyestuffs	C.I. Direct Green 19		6486-58-4	0.012%
	Dyestuffs	C.I. Direct Green 21		8003-52-9	0.012%
	Dyestuffs	C.I. Direct Green 22		6860-33-4	0.012%
	Dyestuffs	C.I. Direct Green 39		6360-57-2	0.012%
	Dyestuffs	C.I. Direct Green 58		110735-26-7	0.012%
	Dyestuffs	C.I. Direct Green 6		4335-09-5	0.012%
	Dyestuffs	C.I. Direct Green 60		6426-56-8	0.012%
	Dyestuffs	C.I. Direct Green 7		6360-64-1	0.012%
	Dyestuffs	C.I. Direct Green 8		5422-17-3	0.012%
	Dyestuffs	C.I. Direct Green 85		72390-60-4	0.012%
	Dyestuffs	C.I. Direct Green 9		6360-62-9	0.012%
	Dyestuffs	C.I. Direct Orange 1		6459-87-6	0.012%
	Dyestuffs	C.I. Direct Orange 10		6405-94-3	0.012%
	Dyestuffs	C.I. Direct Orange 13		6486-43-7	0.012%
	Dyestuffs	C.I. Direct Orange 2		8005-97-8	0.012%
	Dyestuffs	C.I. Direct Orange 30		6420-04-8	0.012%
	Dyestuffs	C.I. Direct Orange 31		6420-03-7	0.012%
	Dyestuffs	C.I. Direct Orange 33		13190-99-3	0.012%
	Dyestuffs	C.I. Direct Orange 6		6637-88-3	0.012%
	Dyestuffs	C.I. Direct Orange 7		2868-76-0	0.012%
	Dyestuffs	C.I. Direct Orange 8		2429-79-0	0.012%
	Dyestuffs	C.I. Direct Red 1		2429-84-7	0.012%

	Dyestuffs	C.I. Direct Red 10		2429-70-1	0.012%
	Dyestuffs	C.I. Direct Red 123		6470-23-1	0.012%
	Dyestuffs	C.I. Direct Red 13		1937-35-5	0.012%
	Dyestuffs	C.I. Direct Red 17		2769-07-5	0.012%
	Dyestuffs	C.I. Direct Red 18		6548-26-1	0.012%
	Dyestuffs	C.I. Direct Red 2		992-59-6	0.012%
	Dyestuffs	C.I. Direct Red 21		6406-01-5	0.012%
	Dyestuffs	C.I. Direct Red 24		6420-44-6	0.012%
	Dyestuffs	C.I. Direct Red 26		3687-80-7	0.012%
	Dyestuffs	C.I. Direct Red 28		573-58-0	0.012%
	Dyestuffs	C.I. Direct Red 29		6426-54-6	0.012%
	Dyestuffs	C.I. Direct Red 33		6253-15-2	0.012%
	Dyestuffs	C.I. Direct Red 37		3530-19-6	0.012%
	Dyestuffs	C.I. Direct Red 39		6358-29-8	0.012%
	Dyestuffs	C.I. Direct Red 42		6548-39-6	0.012%
	Dyestuffs	C.I. Direct Red 43		6486-50-6	0.012%
	Dyestuffs	C.I. Direct Red 44		2302-97-8	0.012%
	Dyestuffs	C.I. Direct Red 46		6548-29-4	0.012%
	Dyestuffs	C.I. Direct Red 52		6797-93-9	0.012%
	Dyestuffs	C.I. Direct Red 53		6375-58-2	0.012%
	Dyestuffs	C.I. Direct Red 59		6655-94-3	0.012%
	Dyestuffs	C.I. Direct Red 60		6486-49-3	0.012%
	Dyestuffs	C.I. Direct Red 61		6470-31-1	0.012%
	Dyestuffs	C.I. Direct Red 62		6420-43-5	0.012%
	Dyestuffs	C.I. Direct Red 67		6598-56-7	0.012%
	Dyestuffs	C.I. Direct Red 7		2868-75-9	0.012%
	Dyestuffs	C.I. Direct Red 72		8005-64-9	0.012%
	Dyestuffs	C.I. Direct Red 73		6460-01-1	0.012%

	Dyestuffs	C.I. Direct Red 74		8003-75-6	0.012%
	Dyestuffs	C.I. Direct Red 88		6459-86-5	0.012%
	Dyestuffs	C.I. Direct Violet 1		2586-60-9	0.012%
	Dyestuffs	C.I. Direct Violet 12		2429-75-6	0.012%
	Dyestuffs	C.I. Direct Violet 17		6426-65-9	0.012%
	Dyestuffs	C.I. Direct Violet 22		6426-67-1	0.012%
	Dyestuffs	C.I. Direct Violet 27		6426-64-8	0.012%
	Dyestuffs	C.I. Direct Violet 28		6420-06-0	0.012%
	Dyestuffs	C.I. Direct Violet 3		6507-83-1	0.012%
	Dyestuffs	C.I. Direct Violet 32		6428-94-0	0.012%
	Dyestuffs	C.I. Direct Violet 36		6472-94-2	0.012%
	Dyestuffs	C.I. Direct Violet 38		6426-77-3	0.012%
	Dyestuffs	C.I. Direct Violet 4		6472-95-3	0.012%
	Dyestuffs	C.I. Direct Violet 42		6459-88-7	0.012%
	Dyestuffs	C.I. Direct Violet 43		6426-63-7	0.012%
	Dyestuffs	C.I. Direct Violet 45		6426-72-8	0.012%
	Dyestuffs	C.I. Direct Violet 85		6507-84-2	0.012%
	Dyestuffs	C.I. Direct Yellow 1		6472-91-9	0.012%
	Dyestuffs	C.I. Direct Yellow 20		6426-62-6	0.012%
	Dyestuffs	C.I. Direct Yellow 24		6486-29-9	0.012%
	Dyestuffs	C.I. Disperse Blue 1		2475-45-8	0.010%
	Dyestuffs	C.I. Disperse Blue 107		12223-01-7	0.010%
	Dyestuffs	C.I. Disperse Blue 124		15141-18-1	0.013%
	Dyestuffs	C.I. Disperse Blue 3		2475-46-9	0.010%
	Dyestuffs	C.I. Disperse Blue 35		56524-77-7	0.013%
	Dyestuffs	C.I. Disperse Blue 7		3179-90-6	0.010%
	Dyestuffs	C.I. Disperse Orange 1		2581-69-3	0.010%
	Dyestuffs	C.I. Disperse Orange 149		85136-74-9	0.013%

	Dyestuffs	C.I. Disperse Orange 3		730-40-5	0.010%
	Dyestuffs	C.I. Disperse Orange 37		12223-33-5	0.010%
	Dyestuffs	C.I. Disperse Red 1		2872-52-8	0.010%
	Dyestuffs	C.I. Disperse Red 15		116-85-8	0.013%
	Dyestuffs	C.I. Disperse Red 17		3179-89-3	0.010%
	Dyestuffs	C.I. Disperse Red 220		65907-69-9	0.013%
	Dyestuffs	C.I. Disperse Yellow 1		119-15-3	0.010%
	Dyestuffs	C.I. Disperse Yellow 23		6250-23-3	0.013%
	Dyestuffs	C.I. Disperse Yellow 3		2832-40-8	0.010%
	Dyestuffs	C.I. Disperse Yellow 39		12236-29-2	0.010%
	Dyestuffs	C.I. Disperse Yellow 49		54824-37-2	0.010%
	Dyestuffs	C.I. Disperse Yellow 7		6300-37-4	0.013%
	Dyestuffs	C.I. Disperse Yellow 9		6373-73-5	0.010%
	Dyestuffs	C.I. Mordant Yellow 16		8003-87-0	0.013%
	Dyestuffs	C.I. Oxidation Base 35		95-80-7	0.003%
	Dyestuffs	C.I. Reactive Black 5		17095-24-8	0.010%
	Dyestuffs	C.I. Reactive Blue 198		84434-51-5	0.010%
	Dyestuffs	C.I. Reactive Orange 12		70161-14-7	0.010%
	Dyestuffs	C.I. Reactive Orange 16		20262-58-2	0.010%
	Dyestuffs	C.I. Reactive Orange 35		70210-13-8	0.010%
	Dyestuffs	C.I. Reactive Orange 4		70616-90-9	0.010%
	Dyestuffs	C.I. Reactive Orange 64		83763-57-9	0.010%
	Dyestuffs	C.I. Reactive Orange 67		83763-54-6	0.010%
	Dyestuffs	C.I. Reactive Orange 86		57359-00-9	0.010%
	Dyestuffs	C.I. Reactive Red 11		12226-08-3	0.010%
	Dyestuffs	C.I. Reactive Yellow 86		61951-86-8	0.010%
	Dyestuffs	Diazo Fast Blue BB		120-00-3	0.013%

Finishing	Antiwrinkle agent	2-Amino-2-methylpropanol hydrochloride		3207-12-3	0.01%
	Antiwrinkle agent	Melamine-formaldehyde copolymer		9003-08-1	0.01%
	Antiwrinkle agent	Urea, polymer with formaldehyde		9011-05-6	0.01%
	Antiwrinkle agent	Glyoxal		107-22-2	0.01%
	Antiwrinkle agent	Melamin		108-78-1	0.01%
	Antiwrinkle agent	Di(hydroxyethyl)amine		114-42-2	0.01%
	Antiwrinkle agent	Dimethylolethyltriazone		134-97-4	0.01%
	Antiwrinkle agent	Dimethylolethyleneurea		136-84-5	0.01%
	Antiwrinkle agent	Tetrahydro-1,3-bis(hydroxymethyl)-4-methoxy-5,5-dimethyl -2(1H)-pyrimidinone		13747-12-1	0.01%
	Antiwrinkle agent	Zinc tetrafluoroborate		13826-88-5	0.01%
	Antiwrinkle agent	N,N'-bis(hydroxymethyl)-urea		140-95-4	0.01%
	Antiwrinkle agent	Dimethyloldihydroxy ethylene urea		1854-26-8	0.01%
	Antiwrinkle agent	Dimethylolpropyleneurea		3270-74-4	0.01%
	Antiwrinkle agent	4,5-Dihydroxytetrahydroimidazol-2-one		3720-97-6	0.01%
	Antiwrinkle agent	Bis(hydroxymethyl)-carbamic acid, ethyl ester		3883-23-6	0.01%
	Antiwrinkle agent	Dimethylol methyl carbamate		4913-31-9	0.01%
	Antiwrinkle agent	Formaldehyde		50-00-0	0.01%
	Antiwrinkle agent	Tetramethylol acetylenediurea		5395-50-6	0.01%
	Antiwrinkle agent	Urea		57-13-6	0.01%
	Antiwrinkle agent	Poly(dimethylsiloxane)		63148-62-9	0.01%
	Antiwrinkle agent	Propylene urea		6531-31-3	0.01%
	Antiwrinkle agent	3,5-Dimethyloluron		7327-69-7	0.01%
	Antiwrinkle agent	Zinc chloride		7646-85-7	0.01%
	Antiwrinkle agent	Zinc nitrate		7779-88-6	0.01%
	Antiwrinkle agent	Magnesium chloride		7786-30-3	0.01%
	Antiwrinkle agent	N-Methylolacrylamide		924-42-5	0.01%
	Repellent	Acrylic acid		79-10-7	0.02%

	Repellent	Melamine-formaldehyde copolymer		9003-08-1	0.02%
	Repellent	Aluminium acetate		139-12-8	0.02%
	Repellent	Ethyl acrylate		140-88-5	0.02%
	Repellent	Methylolstearamide		3370-35-2	0.02%
	Repellent	1-[[(1-oxooctadecyl)amino]methyl]-pyridinium chloride		4261-72-7	0.02%
	Repellent	1-octadecyl-2-imidazolidinone		4991-32-6	0.02%
	Repellent	Aluminumformate		7360-53-4	0.02%
	Repellent	Silicon		7440-21-3	0.02%
	Repellent	Paraffin wax		8002-74-2	0.02%
	Repellent	1-[(C16-18-alkyloxy)methyl]-pyridinium chloride		85507-99-9	0.02%
	Repellent	polyvinyl chloride		9002-86-2	0.02%
	Repellent	Acetic acid ethenylester, homopolymer		9003-20-7	0.02%
	Repellent	Aluminium triacetate		8006-13-1	0.02%
	Flame retardants	Trimethylolmelamine		1017-56-7	0.04%
	Flame retardants	Triethanolamine		102-71-6	0.04%
	Flame retardants	Tris(2-chloroethyl) phosphate	TCEP	115-96-8	0.04%
	Flame retardants	Decabromodiphenyl oxide	DeBDE	1163-19-5	0.04%
	Flame retardants	Tetrakis(hydroxymethyl)phosphonium chloride		124-64-1	0.04%
	Flame retardants	Antimony trioxide		1309-64-4	0.04%
	Flame retardants	Tungsten oxide		1314-35-8	0.04%
	Flame retardants	Tris(1,3-dichloro-2-propyl)phosphate		13674-87-8	0.04%
	Flame retardants	Tetrabromophthalic acid		13810-83-8	0.04%
	Flame retardants	Potassium hexafluorotitanate		16919-27-0	0.04%
	Flame retardants	Dipotassium hexafluorozirconate		16923-95-8	0.04%
	Flame retardants	Tetrakis(hydroxymethyl)-phosphonium phosphate		22031-17-0	0.04%
	Flame retardants	Hexabromocyclododecane	HBCDD	25637-99-4	0.04%
	Flame retardants	Tris(chloropropyl)phosphate		13674-84-5	0.04%
	Flame retardants	Pentabromodiphenylether	PeBDE	32534-81-9	0.04%

	Flame retardants	Tetrakis(hydroxymethyl)phosphonium hydroxide		512-82-3	0.04%
	Flame retardants	Tetrakis(hydroxymethyl)phosphonium ethanedioate		52221-67-7	0.04%
	Flame retardants	Tris(1-aziridinyl)phosphine oxide		545-55-1	0.04%
	Flame retardants	Tetrakis(hydroxymethyl)phosphonium sulfate		55566-30-8	0.04%
	Flame retardants	Tetrachlorophthalic acid		632-58-6	0.04%
	Flame retardants	Titanium tetrachloride		7550-45-0	0.04%
	Flame retardants	Tetrakis(hydroxymethyl)-phosphonium acetate		7580-37-2	0.04%
	Flame retardants	Polyvinylchloride		9002-86-2	0.04%
	Antimicrobial	Copper compounds		7440-50-8	0.08%
	Antimicrobial	Tin compounds		7440-31-5	0.08%
	Antimicrobial	Zinc compounds		7440-66-6	0.08%
	Antistatic	Poly(ethylene glycole)s		260402-71-0	0.03%
	Antistatic	Ethoxylated amines		61791-26-2	0.03%
	Antistatic	Ammonium salts		61789-90-8	0.03%
	Antistatic	Antistatic agent for nylon		260402-75-3	0.03%
	Antistatic	Dihydroxyethyl sulfone		2580-77-0	0.03%
	Antistatic	Diethylenetriamine		111-40-0	0.03%
	Antistatic	Hexamethylenediamine		124-09-4	0.03%
	Antistatic	Lithium chloride		7447-41-8	0.03%
Multipurpose auxiliaries	Washing and chemical additives in formulations	Nonylphenoxypoly(ethyleneoxy)ethanol		9016-45-9	0.7 ppm
Polymer substrate		Nylon-6		25038-54-4	62.7%
		Nylon-6,6		9011-56-6	26.9%