

Chemical Substances in Paper and Paperboard

A study within the government assignment on mapping hazardous chemical substances 2017–2020

PM 4/2019



The Swedish Chemicals Agency is supervisory authority under the Government. We work in Sweden, the EU and internationally to develop legislation and other incentives to promote good health and improved environment. We monitor compliance of applicable rules on chemical products, pesticides and substances in articles and carry out inspections. We review and authorise pesticides before they can be used. Our environmental quality objective is A Non-toxic Environment.

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Article number: 511 334.

Preface

This study was commissioned by the Swedish Chemical Agency and conducted by Goodpoint AB in collaboration with Technical University of Denmark and PP Polymer AB. It is part of the Governmental assignment that the Swedish Government has commissioned the Swedish Chemical Agency to identify hazardous substances, not yet regulated, in chemical products and articles.

This report covers the most common paper articles on the Swedish market and the chemicals used to achieve the desired characteristics of such articles.

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The report is written by Goodpoint AB, Technical University of Denmark and PP Polymer AB. The literature review and data collection have been conducted by the authors and any opinion expressed in this report is theirs and do not necessarily reflect or represent the views or opinions held by the Swedish Chemicals Agency, unless otherwise stated.

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Summary

This report is, one of many, background reports prepared in relation to the Governmental assignment that the Swedish Government has commissioned the Swedish Chemical Agency to identify hazardous substances, not yet regulated, in chemical products and articles.

The paper industry is one of the largest industries in the world and uses a vast amount of chemicals. In everyday life, paper is an important material used in a variety of paper and paperboard consumer articles, such as newspapers and magazines, packaging for shipping and distribution of items, and hygiene papers. Depending on the quality and functionality requirements for the paper articles, paper grades with various characteristics can be used. To achieve specific characteristics, a variety of chemicals are used. In paper production, chemicals can either be used to improve functionality of the paper or in the production process itself. In addition, chemicals are also used on the final paper articles. Common production practices include surface treatment, lamination and printing, where chemicals like polymers and inks are used.

The aim of this project is to identify substances that can be present in consumer articles of paper and paperboard on the Swedish market. This report is a technical review of paper and paperboard and will not focus on the issues regarding inherent hazards or risks with chemicals in the paper industry or any assessment of present chemicals legislation. These issues will be addressed in a later step in the subsequent work of the Governmental assignment by the Swedish Chemicals Agency.

The project was performed in various steps. Firstly, data was collected to develop consumer exposure estimations and identify relevant origins for the paper and paperboard placed on the Swedish market. Secondly, identification of substances potentially used in paper production was performed by reviewing relevant literature in combination with interviews with the industry. To identify the substances and paper grades with the highest relevance to the project, two prioritisation models were developed. One prioritisation model was developed to focus on the substances that had most relevance for paper articles on the Swedish market. Another prioritisation model identified the most relevant paper grades. Finally, a list of substances, with the highest relevance to the aim of the project, was compiled. Focusing on selected substances, literature review and industry surveys provided information regarding the functionality of the substance used in different paper grades and articles. Identified information was regarding substance function and use in different paper grades and paper articles. Furthermore, this list was also sent to the industry to receive further information regarding their use of specific substances.

It was concluded that domestic production had a dominant role for paper articles placed on the Swedish market. No paper grade could be excluded in this study apart from “other paper and board” that was excluded due to its low quantity compared to the other paper grades. The number of identified potential substances related to paper article manufacturing was large (more than 17 000 substances, including duplicates from different information sources) and, hence, there was a need to prioritise among the substances. It is worth noting that the majority of substances were related to the printing industry. During the prioritisation step, it was decided that the focus would be on substances that could occur on the Swedish market in all paper grades apart from “other paper and board”. It was found that different paper articles for consumer use commonly had different chemical composition. It was also found that the required function could be achieved by a variety of substances and that substances could have more than one function in the manufacturing of paper articles.

In conclusion, this report demonstrates the various steps to identify the linkage between paper articles, paper grade, chemical mixtures and specific substances. In addition to the results presented in this report, detailed lists of identified substances are provided in the separate file “Appendix B1”.

Sammanfattning

Den här rapporten är en av underlagsrapporterna inom regeringsuppdraget om kartläggning av farliga ämnen som ännu inte är begränsade inom EU.

Pappersindustrin är en av världens största industrier och en stor användare av kemikalier. Papper och kartong används i vårt dagliga liv i en mängd olika konsumentvaror t.ex. dagstidningar och tidskrifter, förpackningar för transport och distribution av varor, hygienpapper. Beroende på kvalitets- och funktionskrav för pappersvarorna kan pappersmaterial som har olika egenskaper användas. För att uppnå dessa specifika egenskaper används en rad olika kemikalier. Under papperstillverkningen kan kemikalier användas för att antingen förbättra papprets funktion eller för att påverka tillverkningsprocessen. Dessutom används kemikalier till de slutliga pappersvarorna. Vanliga produktionsmetoder inkluderar ytbehandling, laminering och tryck där kemikalier som polymerer och tryckfärg används.

Syftet med rapporten är att identifiera ämnen som kan förekomma i konsumentvaror av papper och kartong på den svenska marknaden. Konsultrapporten är en teknisk genomgång av papper och papp och fokuserar inte på frågorna om farligheter och risker med kemikalier eller någon bedömning av befintlig kemikalielagstiftning. Dessa frågor kommer Kemikalieinspektionen att arbeta vidare med i det fortsatta arbetet med regeringsuppdraget som helhet.

Projektet utfördes i flera olika steg. Först samlades data in för att uppskatta konsumentexponering samt identifiera tillverkningsland för pappersvarorna på den svenska marknaden. I ett andra steg identifierades ämnen som potentiellt används vid papperstillverkning genom en litteraturstudie av relevanta källor samt intervjuer med olika parter inom pappersindustrin. För att identifiera ämnena och papperskvalitéer med högst relevans för projektet utvecklades två prioriteringsmodeller. En prioriteringsmodell utvecklades för att prioritera de ämnen som är mest relevanta för pappersvaror på den svenska marknaden. Den andra modellen användes för att identifiera de mest relevanta papperskvalitéerna. Slutligen sammanställdes en förteckning med de ämnena med högst relevans för projektet. Med fokus på de utvalda ämnena genomfördes litteraturstudier och branschundersökningar. Dessa undersökningar gjordes för att få fram information om ämnenas funktionalitet i olika papperskvalitéer och varor. Förteckningen sammanställde bl.a. information om ämnens funktion samt de pappersvaror och/eller papperskvalitéer där ämnet har identifierats. Förteckningen skickades även ut till industrin för att erhålla ytterligare information om ämnenas användning.

Studien visade att pappersvaror på den svenska marknaden i stor utsträckning var tillverkat i Sverige och att det enbart var papperskvalitén "övrigt papper och kartong" som kunde uteslutas. Uteslutningen baserades på att "övrigt papper och kartong" konsumeras i mycket små kvantiteter jämfört med andra papperskvalitéer. Antalet identifierade ämnen som skulle kunna förekomma vid tillverkning av pappersvaror var betydande (mer än 17 000 ämnen), där majoriteten av ämnen var kopplade till tryckeribranschen. Efter att den nämnda prioriteringsmodellen för ämnen hade utvecklats, bestämdes det att ämnen som kan förekomma på den svenska marknaden skulle prioriteras och studeras närmre. För de prioriterade ämnena sammanställdes information om ämnenas funktion, och vilka pappersvaror samt papperskvalitéer där ämnena hade identifierats. Denna information kunde sammanställas med hjälp av den utförda litteraturöversikten, en enkätundersökning samt intervjuer med industrin.

I studien kan vi notera att pappersvaror har olika kemisk sammansättning beroende på dess slutliga användning. Det är också betydelsefullt att poängtera att nödvändiga egenskaper kan uppnås med en mängd olika ämnen samt att använda ämnen kan ha fler än en funktion under papperstillverkning.

Sammanfattningsvis åskådliggör denna rapport kopplingen mellan pappersvaror, papperskvalitéer, kemiska blandningar samt specifika ämnen. Resultaten presenteras både i denna rapport och i den separata bilagan ”Appendix B1”.

Definitions and Abbreviations

Additive	Something that is added, as one substance to another or to a process, to alter or improve the general quality or to counteract undesirable properties.
Alum	A class of chemical compounds e.g. potassium aluminium sulphate.
Anti-foaming agents	Chemical additives that reduces and hinders the formation of foam in water-borne mixtures used in the production of paper and paperboard.
Articles	As in (EC) No1907/2006, an object which during production is given a special shape, surface or design that determines its function to a greater degree than its chemical composition. In this report, the term is used exclusively for paper articles.
Biocides or biocidal product	As in (EU) no 528/2012, a substance that contains one or more active substances with the intention of destroying, deterring, rendering harmless, preventing the action of, or otherwise exerting a controlling effect on any harmful organism by any means other than mere physical or mechanical action.
Bleaching agents	Substances used to bleach the paper in the production phase.
BMEL	Bundesministerium für Ernährung und Landwirtschaft (Federal Ministry for Food and Agriculture of Germany)
Bursting strength	The resistance of the material against bursting when an external force is applied.
CEPI	Confederation of European Paper Industries. CEPI represents more than 90% of the European paper industry, in terms of paper and paperboard production. Sweden, among other 18 countries, is a member of CEPI.
Chemical	Either a single substance, mixture or group of substances
Chemical pulp	Pulp produced from chemically digested wood.
Chelating agent	A substance that coordinates with a metal to form a chelate, often used to trap or remove metal ion in the waste water treatments from the paper industries.
Chemi-Thermomechanical (CMT) pulp	Pulp produced from wood impregnated with a chemical treatment before mechanical pulping.
Coating	The process of applying, to the surface of a paper or paperboard to improve properties such as hydrophobicity, gloss, printability, optical properties etc.
Coating chemicals	As according to CEPI 2014; Chemicals used to improve appearance and performance of printed paper and paperboard.
Crush strength	The resistance of a paperboard construction to crush.
DPR	Danish Product Register
EC (no) 1907/2006	Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).
EC no 1935/2004	Regulation (EC) No 1935/2004 of the European Parliament and of the Council of 27 October 2004 on materials and articles intended to come into contact with food and repealing Directives 80/590/EEC and 89/109/EEC.
EU (no) 528/2012	Regulation (EU) No 528/2012 of the European Parliament and of the Council of 22 May 2012 concerning the making available on the market and use of biocidal products.
ECHA	European Chemicals Agency
EEA	The European Economic Area (EEA). The EEA includes EU countries and Iceland, Liechtenstein and Norway. It allows them to be part of the EU's single market.
Elemental chlorine free (ECF)	A bleaching process using chlorine dioxide, but without use of chlorine gas.
Embedded	Substances that are bonded to the material by covalent type or hydrogen bonding. Bonded chemicals are expected not to extract and evaporate, thus stay in the material.
Embossed	A method to raise paper creating patterns and designs
EU	European Union
EUPIA	European Printing Inks Association

FAO	Food and Agriculture Organization of the United Nations
FDHA	Swiss Federal Department of Home Affairs
Fillers	As according to CEPI, fine pigments, generally white and usually of mineral origin, incorporated in the stock pulp during the manufacture of paper or paperboard.
Function chemicals	As according to CEPI 2014, means chemicals added to attribute specific properties to paper e.g. hydrophobicity, softness etc.
Hardwood	Wood from non-coniferous trees (trees not having needles or cones) (e.g. birch, eucalyptus, aspen, beech, hornbeam, ash, maple, acacia, quercus-cerris, oak, alder, poplar).
Import	The transfer of articles from another country, within the EU or from a third country, to place on the Swedish market
Importer	Any natural or legal person established within Sweden that purchase articles from another country within the EU or from a third country to place on the Swedish market.
Item	An article not made of paper material.
Lightweight coated	Coating layer of 12g/m ² /side.
Lignin	An organic substance giving mechanical strength to the cell wall of plants.
Linting	The tendency of a paper to shed loosely bound material during printing.
Mechanical pulp	Pulp produced by grinding wood with a stone or steel discs to separate wood fibres.
Medium coating	Coating layer of 12-25g/m ² /side.
NIAS	Non-Intentionally Added Substances.
Non-embedded	Substances not bonded to the material (as opposite to embedded) and may exist in free form in the paper material.
NPR	Norwegian Product Register
Paper	Materials in the form of a coherent sheet or web.
Paper article manufacturing	The process to manufacture paper articles, including paper production and additional processes (printing, gluing etc).
Paper machine	The machine in which the paper web is formed from pulp.
Paper material	Material of paper or paperboard i.e. material made of pulp.
Paperboard or board	A thick paper-based material typically characterised with a grammage above 250 g/m ² .
PFAS	Perfluorinated alkylated substances
Process chemicals	As according to CEPI 2014; chemicals used to optimise costs and increase machine efficiency e.g. prevent microbial growth, minimise need volume substrate used to gain same effect, etc.
SCB	Statistics Sweden or Statistiska centralbyrån
Sizing	Addition of chemical additives either to the stock pulp (internal sizing) or to the surface of paper or paperboard (surface sizing), in order to increase its resistance to the penetration and spreading of aqueous liquids, for example printing ink. Surface sizing may also be used to increase the surface strength of paper and paperboard.
Softwood	Wood from coniferous trees (e.g. pine, spruce, fir, hemlock, larch, cedar).
SPR	Swedish Product Register
Stock preparation	The process of making pulp form of fibres water and various chemical additives.
Stone groundwood pulp (SGW)	Pulp produced from mechanically grinded wood.
Substance	As in Regulation (EC) No 1907/2006; A chemical element and its compounds in the natural state or obtained by any manufacturing process, including any additive necessary to preserve its stability and any impurity deriving from the process used, but excluding any solvent which may be separated without affecting the stability of the substance or changing its composition.
Supercalendered (SC)	A calender with a number of rollers for giving a high finish or gloss to paper.
Surface treatment chemical	Finishing chemicals to improve appearance and performance of printed paper and paperboard.

Swedish Forest Industries Federation	The forest, pulp and paper industry interest organisation in Sweden, Skogsindustrierna (in Swedish).
Thermomechanical Pulp (TMP)	Pulp produced by a mechanical process in which wood chips are softened by pre-heating under pressure prior to a pressurised refining stage.
Tinctorial strength	The relative ability of a pigment or dye to impart colour value to a printing ink.
Totally chlorine free (TCF)	A bleaching process using no chlorine or chlorine substances.
Wet strength agents	Additives used to increase the mechanical properties of paper under wet conditions.

1 Aim, overview of report and delimitations

1.1 Aim

Identify chemicals in consumer articles of paper and paperboard in Sweden. The report was divided in three parts, details of which are provided in the Section 1.2 below.

1.2 Overview of report

The report can be described in three main parts (Figure 1). The first part of the report consists of an overview of paper material and production processes. In addition, this part (see Section 2) describes the chemicals used in the production to achieve the desired material characteristics of the end-use. The information is collected from a variety of sources, such as literature study as well as surveys and interviews with the paper industry.

The second part (see Section 3), consists of the analysed results from data collection. These results are used to develop two prioritisation models, one model to prioritise paper grades and one to prioritise substances. Prioritisation of relevant paper grades is performed by collecting data on quantities of paper grades and exposure estimations. The prioritisation of substances is based on the origin of paper grades as well as the relevance of the substances to paper production. The substances are prioritised in Appendix B1 into three levels; high, medium and low priority.

Finally, the report describes the linkage of the “high priority” substances (see Appendix B1) to paper grades and paper articles. The information to perform the linkage is collected from a variety of sources, such as literature studies as well as surveys and interviews with the paper industry. For more information regarding methodology, see Appendix A1.



Figure 1. The three main parts of the report; 1) Data collection, 2) Analysis and prioritisation, 3) Linkage between substances and paper

1.3 Delimitations

During the project, various delimitations have been made due to data and time restraints. The delimitations are explained in more detail in Appendix A2. Furthermore, prioritisations also have been made during the project, these prioritisations are described and discussed in the report.

2 Introduction

Paper and paperboard are used by consumers in everyday life. The articles of paper and paperboard have multiple forms and functions. These articles are a necessity for our modern lifestyle and can for instance be used to store and distribute information, for packaging and protection of foods and cosmetics or for cleaning purposes. The paper industry uses a large amount of different chemicals to achieve the specific characteristics of the final paper materials.

Paper are materials based on cellulose fibres from plants. The most commonly used raw material for paper today is wood fibres from various types of trees. Recycling of paper is another source of raw material for paper products. The properties of the fibres from a certain wood species is one factor that determines the final paper quality. Other important factors are the methods used to separate the fibres from the wood (see pulp grades below), conditions during the paper production and addition of functional chemicals to be available in the paper during the use phase.

Depending on the intended use in articles, paper is converted in various processes (lamination, cutting, printing, binding, folding, etc) to e.g. books, newspapers, boxes, liquid containers, and household rolls.

2.1 Pulp grades

To achieve the various desired properties for the paper articles, several types of pulping processes can be used. The resulting pulps have different characteristics suitable for their specific end-uses. In this section, there is an overview of the various types of pulp and pulping processes. Pulp is usually divided into four groups; mechanical, chemical, recycled fibre or textile fibre pulp. These groups can further be divided into subgroups (Figure 2).

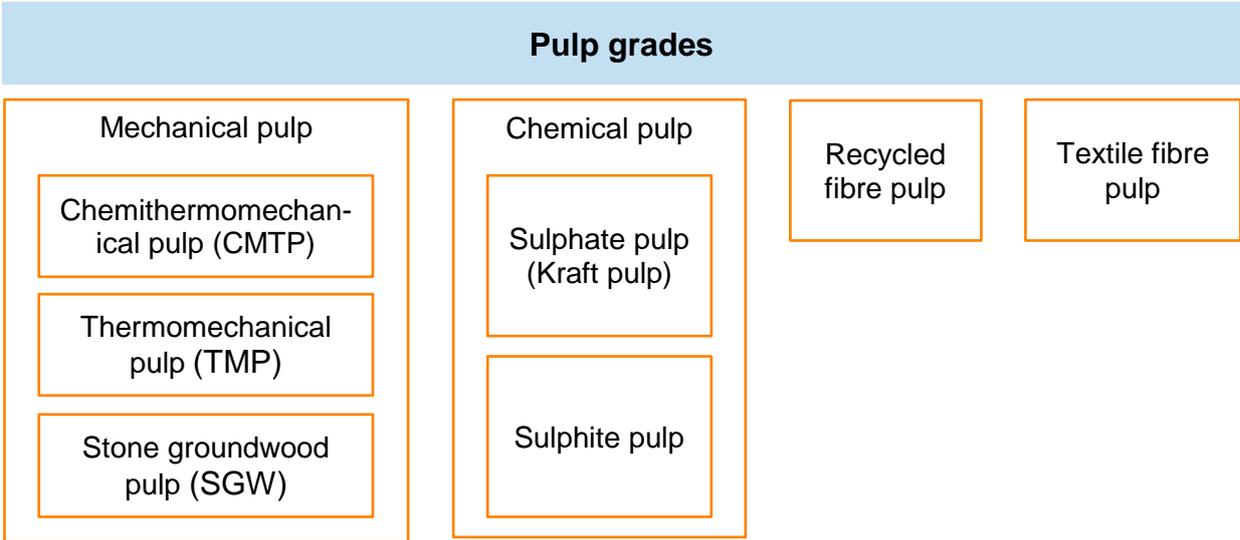


Figure 2. Pulp is categorised by FAO into four major groups where two groups have sub-groups. The four major groups are mechanical, chemical, recycled fibre and textile pulp. Mechanical pulp has three sub-groups; chemi-thermomechanical pulp (CMTP), thermomechanical pulp (TMP) and stone groundwood pulp (SGW). Chemical pulp has two sub-groups; sulphate pulp and sulphite pulp.

Within the groups and subgroups, both bleached and unbleached pulp grades may be available. The purpose of the bleaching of the pulp is not only to make it brighter to contrast with printing ink. Other benefits from the bleaching can be removal of wood particles to avoid mechanical breaks in the paper during the following production stages or removal of odorous substances in papers for food contact.

In addition to fibres, paper pulp usually contains limited number of substances added in the pulping process. Substances that are found in pulp are either residues from the raw material (these may be wood specific), residues from process chemicals or unintentional contamination.

Table 1. Process chemicals used in the pulping process and their purposes.

Type of pulp	Pulp sub-groups	Identified chemicals and their purposes
Mechanical pulp	Thermomechanical pulp	Na ₂ SO ₃ (if softwood) – Dissolve lignin NaOH or H ₂ O ₂ (if hardwood) – Dissolve lignin and bleach pulp
	Chemi-Thermomechanical pulp	Pre-chemical impregnation with strong or weak alkali Na ₂ SO ₃ (if softwood) – Dissolve lignin NaOH or H ₂ O ₂ (if hardwood) – Dissolve lignin and bleach pulp
	Stone groundwood pulp	Na ₂ SO ₃ (if softwood) – Dissolve lignin NaOH or H ₂ O ₂ (if hardwood) – Dissolve lignin and bleach pulp
Chemical pulp	Sulphate pulp	NaOH and Na ₂ S (white liquor) – Dissolve lignin Chlorine dioxide, oxygen, hydrogen peroxide, ozone – bleach pulp
	Sulphite pulp	Bisulphites – Dissolve lignin
Recycled pulp	Recycled pulp	NaOH – Deink pulp Soap – Deink pulp Fatty acids - Deink pulp H ₂ O ₂ – Bleach pulp Chelating agents – improve process efficiency e.g. bleaching
Textile fibre pulp	Textile fibre pulp	-

2.1.1 Mechanical pulp

Mechanical pulp is made by mechanically grinding the wood against a stone, or more commonly between steel discs, to separate the fibres from the lignin. Mechanical pulp can be bleached or unbleached and made from either softwood or hardwood. For more information regarding softwood and hardwood, see Section “Definitions and abbreviations”. This pulping process results in a 95% yield from the wood and pulp with mixed length of the fibres. The remaining lignin content is higher for mechanical pulp compared to chemical pulp (see Section 2.1.2). The mechanical pulp can be categorised into three different pulp grades defined by different pre-treatments of the wood; thermomechanical pulp, chemi-thermomechanical pulp and stone groundwood pulp (Figure 2 and Table 1).

Mechanical pulping produces a paper material with a yellowish to grey tone, high opacity, smooth surface and low paper strength. Mechanical pulp is the main pulp used for the graphic

paper grades newsprint and mechanical paper, but is also common to use in some packaging paper as well as sanitary and household paper^{1,2}.

Thermomechanical pulp is a pulp where the wood has been softened by pre-heating to make the separation of fibres from lignin more effective during the mechanical grinding. This also results in longer fibres and lighter colour of the pulp.

Chemi-Thermomechanical pulp is a pulp where the wood has been pre-heated and chemically treated with a weak (softwood) or a strong (hardwood) alkaline impregnation before the mechanical grinding process. This gives a lighter colour and better strength properties than thermomechanical pulp.

Stone groundwood pulp is a pulp where the wood only has been mechanically grinded, resulting in relatively short fibres^{3,4}.

2.1.2 Chemical pulp

Chemical pulp is made in a process where woodchips are cooked with chemicals under high pressure to remove lignin from the fibres. Chemical pulp can be bleached or unbleached. This process of cooking the woodchips will result in a pulp with low lignin content, long fibres and only a 45% yield from the wood, as half of the wood will dissolve into something that is called a black liquor, which is removed before further processing such as bleaching.

Chemical pulping will result in a paper material with good paper strength and high brightness after bleaching. Chemical pulp is mainly used for paper grades that require high quality and is the main pulp used for sanitary and household paper, woodfree paper as well as packaging paper^{3,4}. Furthermore, it can be used in most paper grades to increase the strength properties of the paper material^{3,4}.

Sulphite pulp is a pulp where the woodchips have been pre-boiled in a sour cooking liquor with a low or neutral pH-value⁵ in a pressure vessel. The cooking liquor consists of bisulphites of ammonium, calcium, magnesium or sodium. The bisulphite is used to extract the lignin from the woodchips^{4,6}.

Sulphate pulp (kraft pulp) is a pulp where the woodchips have been pre-boiled in a cooking liquor (white liquor). This white liquor consists of either sodium hydroxide or a mixture of sodium hydroxide and sodium sulphide (to increase the pH-value to 13–14)⁷

2.1.3 Recycled fibre pulp

The recycled pulp is manufactured from used paper and paperboard. Depending on the quality requirements for the final paper article (e.g. brightness), recycled pulp sometimes needs to be de-inked which can be done by e.g. sodium hydroxide, resulting in deinked fibres. Other chemicals that are used to de-ink paper during recycling are surfactants (i.e. soaps) and fatty acids; these chemicals promote formation of larger ink particles and make the ink-particle surfaces more hydrophobic and, therefore, promote the separation of ink from the pulp composition.

¹ Paperonline 2017b

² Paperonline 2017c

³ Paperonline 2017b

⁴ Paperonline 2017c

⁵ Skogssverige 2017

⁶ CEPI 2014

⁷ JRC 2015

In addition, the recycled pulp is often bleached with hydrogen peroxide, hydrosulphite or formamidine sulphinic acid. Chelating agents may be used to enhance the effectiveness of other process chemicals. Recycled pulp can be used in most paper grades⁷.

After dissolution, recycled fibres are mostly used integrated at the same site to produce paper again. Those pulps are thus not placed on the market to the same extent as pulps from virgin fibres are.

2.1.4 Textile pulp

Textile pulp is a group of pulps that includes straw pulp, bamboo pulp, bagasse (sugar cane) pulp, esparto pulp and textile pulp⁸. It can be used in file-resistant paper to increase the life time of the paper. Usage of textile pulp is very rare and, hence, considered to be outside the scope of this report

2.2 Paper material

Paper materials can be categorised into different grades of paper (Figure 3 and Table 2) based on material characteristics such as fibre- and chemical composition (for more information see Section 2.1 and 2.4), function and end-use. Paper grades are commonly categorised into four major groups, largely based on end-use purpose; graphic papers, packaging papers, sanitary and household papers and other paper and board. As seen in Figure 3, graphic papers and packaging papers are further categorised into sub-grades based on fibre composition, material characteristics and surface application^{8,9}. The sub-grades for graphic papers are; newsprint, mechanical paper and woodfree paper, and for packaging papers; wrappings, case material and cartonboard. Sanitary and household and other paper and board can be considered as both paper grades and paper sub-grades.

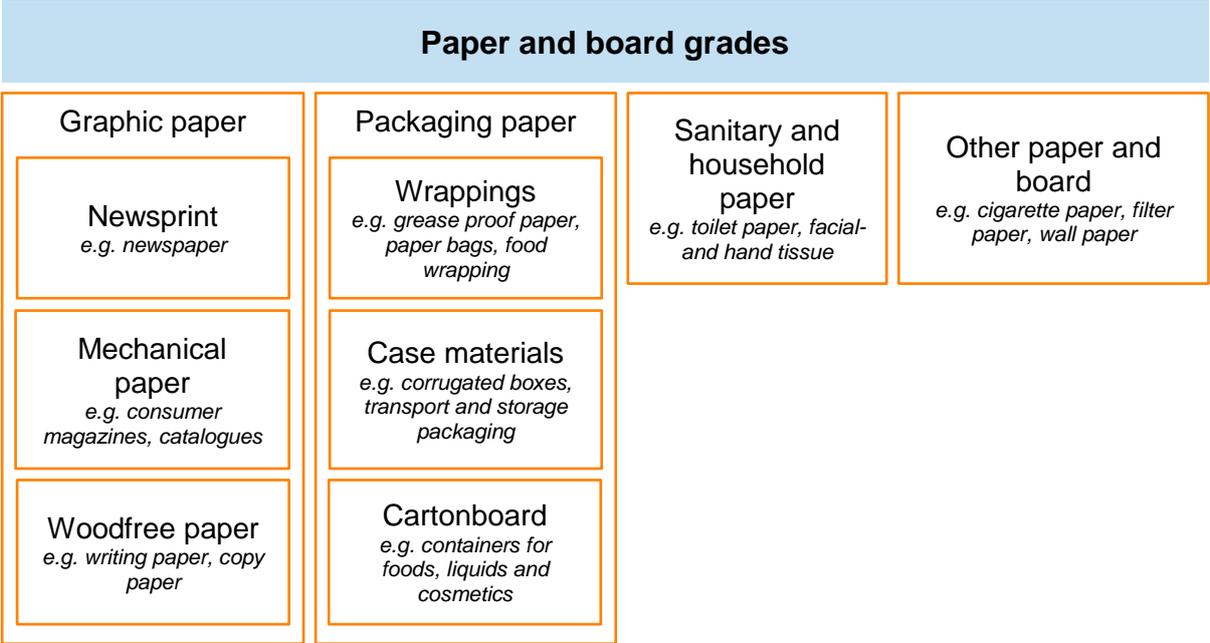


Figure 3. Categorisation of paper material according to CEPI. Paper grades are categorised by CEPI into four major groups, largely based on end-use purpose; graphic papers, packaging papers, sanitary

⁸ CEPI 2014
⁹ RISI 2017a

and household papers and other paper and board. Graphic papers and packaging papers are further categorised into the subgrades based on fibre composition, material characteristics and surface application.

2.2.1 Graphic papers

The graphic paper grade is mainly papers used for storing, collecting and distributing information where typical consumer articles include newsprint, magazines and copy printing papers. The sub-grades of graphic papers are newsprint (used for newspapers), mechanical paper (used for magazines) and woodfree paper (used for copy printing papers). See Figure 3 and Table 2.

The sub-grades are largely based on the pulp used, type of surface application (e.g. coated/uncoated/supercalendered) and application of the paper material^{10,11}. For more information regarding pulp, see Section 2.3. Paper characteristics are good printability properties as the final articles are largely produced for graphic and decorative printing purposes^{10,12,13}

2.2.2 Packaging papers

This grade comprises articles mainly used for transportation packaging, distribution and protection end-uses. The sub-grades are largely defined by final end-use and, thus, material characteristics and include wrappings, case materials and cartonboard (Figure 3)^{10,11}.

Wrapping material is commonly used for packaging and wrapping of various articles for distribution and protection purposes. Paper materials can be sack kraft, wrapping kraft and grease-proof papers. Typical end-uses include bags and wrappings for food as well as baking and cooking papers^{10,13}.

Cartonboard is used for frozen food cartons, liquid containers as well as cosmetic packaging. Desired properties, in this paper grade, are creasing and folding abilities, printability and, depending on the end-use, relevant barrier. For liquids, antiseptic packaging should be used for hygienic purposes^{10,13}.

Case materials are corrugated boards typically used for corrugated boxes, transport packaging, storage and item display. Characteristics for case materials are that they are composed of different layers. The outer layers are called liners and include kraftliner (virgin fibres) and testliner (recycled fibres) whilst the middle layer is called fluting and can either be semi-chemical fluting or recovered paper-based fluting¹⁰. Important properties of corrugated boards are bursting- and crush strength as the boxes need to be able to resist pressure¹⁴

2.2.3 Sanitary and household papers

This grade comprises a wide range of tissue papers and hygienic papers, such as toilet paper and household paper (Figure 3). Other typical end-uses are facial and hand tissues, sanitary towels, baby nappies and napkins. Characteristic properties of articles, in this grade, are high wet- and dry strength, high purity, high absorption capacity and softness^{10,11,13,15}.

¹⁰ CEPI 2014

¹¹ JRC 2015

¹² Paperonline 2017a

¹³ RISI 2017b

¹⁴ Paperonweb 2017

¹⁵ RISI 2017a

2.2.4 Other paper and board

The grade other paper and board includes a wide range of papers and paperboards with vast variation in paper properties and end-uses. Examples of end-uses are cigarette papers, envelope paper, felt paper, filter papers, gypsum liners, wallpaper base and special papers for insulating, roofing, waxing, asphaltting and other specific applications. Due to the variety in paper properties and end-uses, this paper grade is not listed in Table 2.

Table 2. Different paper grades and their specific material properties, pulp composition and typical end-use.

Paper grade	Sub-grade	Paper properties	Pulp composition	Typical end-use
Graphic papers	Newsprint	Printability	Bleached mechanical pulp or de-inked recycled paper or a blend of both	Newspapers
	Mechanical paper		Mechanical wood-pulp	Magazines, catalogues, advertising materials and books
	Woodfree paper		Bleached chemical pulp	Papers for writing, copy printing, books and other office papers.
Packaging paper	Wrappings	Grease proof proof in some of the applications	Unbleached or bleached mechanical pulp or chemical pulp	Paper bags for flour, sugar, groceries or other carrier bags, baking or cooking papers and wrappings for food.
	Cartonboard	Creasing abilities, printability, relevant barrier properties	Unbleached or bleached mechanical pulp or chemical pulp	Folding cartons for frozen food, cosmetics and liquids.
	Case materials	Bursting- and crush strength	Unbleached or bleached mechanical pulp or chemical pulp	Corrugated boxes, transport packaging, storage and item display.
Sanitary and household paper	Sanitary and household paper	Wet strength ¹⁶ and dry strength, high absorption capacity and softness and high purity	Bleached virgin pulp or recovered fibres or a blend of both.	Toilet paper
			Bleached virgin pulp or recovered fibres or a blend of both.	Facial and hand tissues, toilet tissue, baby nappies and napkins
			Bleached virgin pulp or recovered fibres or a blend of both.	Sanitary towels

2.3 Key processes in the paper production process

The production of paper can vary considerably depending on kind of paper produced and the raw materials used in the process. Nonetheless, most types of paper and paperboard

¹⁶ Excluding toilet paper

production processes include the following key processes; stock preparation, paper machine processes and optional finishing processes (Figure 4)^{17,18}.

Chemicals are used throughout the paper production process. The chemicals can either be added to stock preparation or in steps further down the production line.

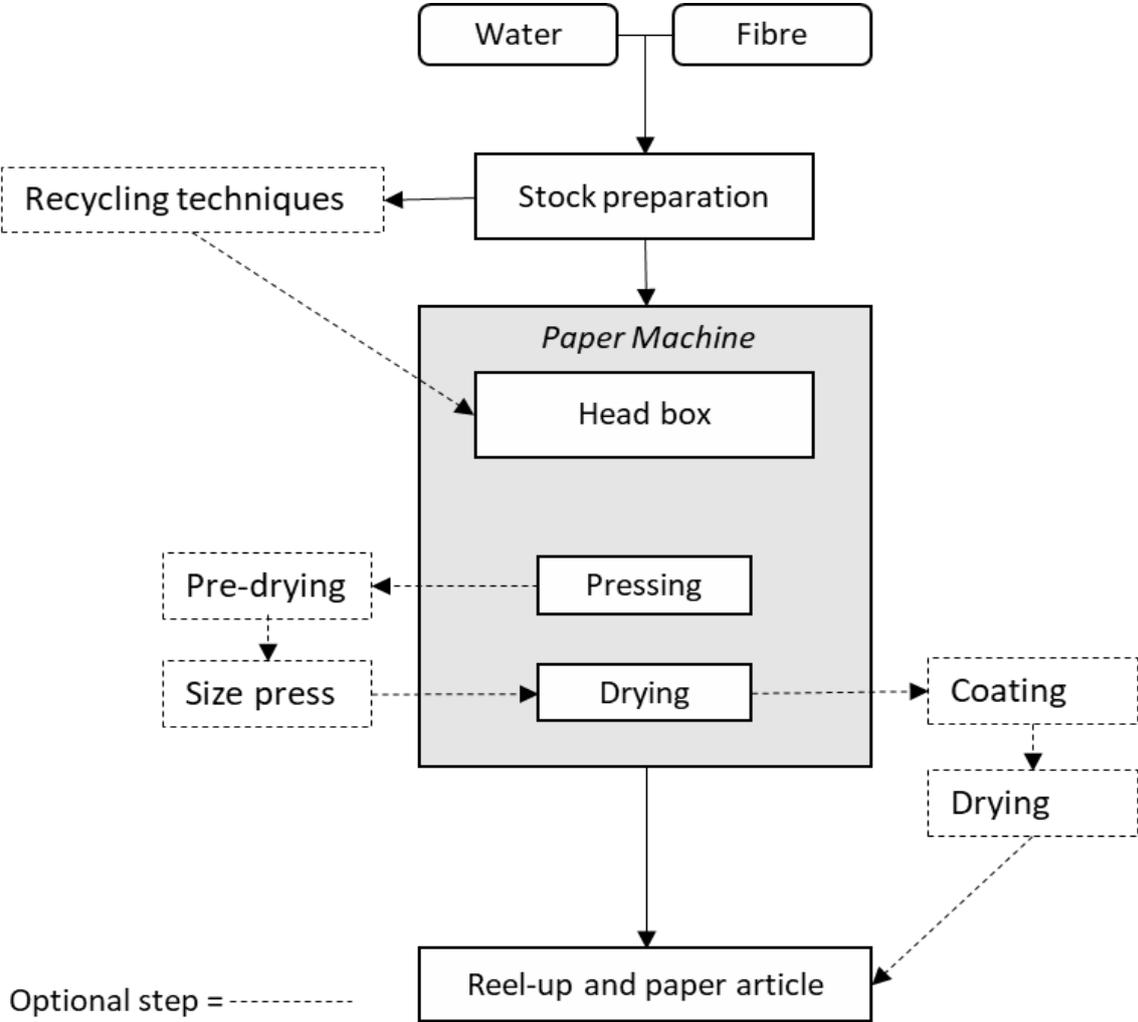


Figure 4. Key processes in the paper production process. Dotted lines and boxes represent optional steps (modified from OECD 2014).

2.3.1 Main steps during the production process

Stock preparation

Stock preparation is the process where raw materials in the form of different types of pulp fibres are mixed with water and various chemicals to form a fibre suspension or furnish. A cleaning stage during the stock preparation is aimed to remove contaminants and impurities from the fibres^{18,19} The fibre suspension is the input to the paper machine (Figure 4). For more information regarding the chemicals, see Table 3.

¹⁷ JRC 2015
¹⁸ OECD 2014
¹⁹ CEPI 2014

Paper machine processes

Following the stock preparation, the pulp stock enters the paper machine (Figure 4). The paper machine can be described as a large dewatering device consisting of a head box, a press section and a drying section. In this part of the process, paper is formed and many of the properties of the paper are determined. The furnish from the stock preparation is diluted with water and pumped onto a moving mesh in the head box together with chemicals such as fillers and dyes. On the mesh, water is drained from the fibre suspension to form a solid paper web. The solid paper web is then transferred to the pressing and drying section.

2.3.2 Optional steps during the finishing process

Depending on what kind of paper is produced, the manufacturing process can include additional or optional steps (Figure 4) to improve quality and give the paper its desired properties.

Sizing

Sizing is when substances (sizing agents) are applied to or incorporated into paper to act as a protective filler or coating. It is used during paper production to reduce the ability of paper, when dry, to absorb liquids. Ink and paint will, therefore, remain on the surface of paper and dry rather than be absorbed into the paper.

There are two kinds of sizing; internal and surface sizing. Internal sizing occurs during the stock preparation by adding sizing agents directly to the furnish to increase strength and, as mentioned above, reduce the paper's capacity to absorb liquids. Surface sizing occurs during the drying process by adding sizing agents onto the surface of the paper web. Surface sizing increases the wet and dry strengths to avoid dusting of the paper during printing processes (e.g. offset printing) as well as making paper hydrophobic or water repellent. Surface sizing takes place in the size press (see Figure 4).

Colouring and optical brightening

Colorants and optical brightening agents are added to adjust the shade of the final paper. Colouring decreases the brightness of the paper and optical brightening makes the paper appear whiter.

Colouring and optical brightening can either be performed during the stock preparation (Figure 4) by adding chemicals directly to the furnish (stock dyeing) or later in the process by applying a coating onto the surface of the paper (surface dyeing). Surface dyeing is rarely used because it is difficult to obtain an evenly dyed surface. The fibre type and intended use of the final paper determine what kind of dye that is most suitable, e.g. basic dyes, direct dyes or acidic dyes. Surface dyeing is not shown in Figure 4.

Coating

The coating process is normally carried out to improve the surface properties of the paper, such as to improve printing, gloss, hydrophobicity, etc.²⁰ (Figure 4). During coating, a mixture of e.g. a solvent (incl. water), pigments and binders is applied to one or both sides of the paper to obtain above mentioned surface properties.

²⁰ OECD 2014

Table 3. Chemicals added during the various production steps

Step in the process	Chemicals added	Example of substances
Stock preparation	Chemicals e.g. resins, wet strength agents, bleaching agents, dyes and fillers can be added.	See Table 4 for details
Processes in the paper machine	Chemicals e.g. drainage agents, retention agents, fillers, sizing agents, strengthening agents, dyes, biocides and optical brighteners can be added.	See Table 4 for details
Sizing (optional finishing)	Chemicals e.g. starch or synthetic sizing agents are used.	Starch or alkyl ketene dimer and polymers based on acrylic esters, maleic acid esters and acrylonitrile are used.
Colored and optical brightened paper (optional finishing)	Chemicals e.g. dyes, pigments or optical brighteners are used as well as fixing agents to improve dye fixation.	Example of pigments are azo- and phthalocyanine pigments and carbon black.
Coating (optional finishing)	Chemicals e.g. a mixture of water, pigments, binders are applied to one or two sides of the paper to obtain certain surface properties.	<p>Typical binders are carboxylated styrene-butadiene, styrene acrylonitrile or acrylic latexes.</p> <p>Starch can be used to add stiffness.</p> <p>Stearates (calcium and ammonium) are used to provide lubrication and surface texture.</p> <p>Pigments such as fine clay, talc or calcium carbonate can be used to obtain the right shade of the paper.</p>

2.4 Chemicals in the paper and paperboard industry

In the pulp and paper production processes various mixtures of substances are used to optimise production quality and obtain specific paper properties for the end-use. The chemicals can be divided into three main groups; process chemicals, functional chemicals and coating chemicals. All chemicals serve distinct functions in the paper production process and influence the final paper quality. However, specific substances can belong to more than one group e.g. hydrogen peroxide can be used as a process chemical used to prevent bacteria growth in the paper machine but can also be used as a preservative in a coating mixture to enhance the performance of the coating or a bleaching chemical in the pulp production. Depending on application, the final paper product may comprise as much as 45 % of its weight in fillers, coating additives and other paper production chemicals²¹.

To conduct risk assessments, it is important to establish if the functional and coating chemicals in question are embedded or non-embedded in the final paper article. If a chemical is not embedded the risk for release is higher. In general, only residues of process chemicals,

²¹ JRC 2015

if any, can be expected to be detected in final paper articles. Therefore, process chemicals are not regarded as high-risk chemicals.

For definitions regarding process, functional and coating chemical as well as embedded and non-embedded, see Section “Definitions and abbreviations”. In Appendix B1, a detailed description of relevant substances and their functions are listed. For more information regarding the structure and usage of Appendix B1, see Section 3.3.1 (see sub-sections “List of prioritised substances” and “Guideline- List of prioritised substances”).

Chemicals in pulp and paper production

<p>Process chemicals</p> <p>Retention and drainage agents, fixatives, anti-foaming agents, dispersing agents, wet end sizing agents, biocides, bleaching agents, de-inking agents, cleaners and surfactants.</p>
<p>Functional chemicals</p> <p>Wet and dry strength agents, softeners, mineral fillers, starch, dyes and optical brightening agents.</p>
<p>Coating chemicals</p> <p>Synthetic binders, coating additives, rheology modifiers, starch, greaseproof and/or waterproof agents.</p>

Figure 5. Chemicals used in the pulp and paper production.

2.4.1 Process chemicals

Process chemicals are used in the pulp and paper making processes to change the chemical and physical properties of the fibres but also to optimise production quality and increase the economic efficiency by improving operations in the production as well as influence the final paper quality. Chemicals used can differ between pulp and paper mills and is mainly based on the raw material quality and input^{22,23,24}. See Appendix B1 for details.

Bleaching agents

Bleaching agents are added to the fibre suspension for discoloration. Bleaching is performed on both recycled paper and virgin fibres to decolour residual inks and dyes and natural colorants of the fibres. Commonly, chlorine dioxide, oxygen, hydrogen peroxide and sodium hydroxide are used as bleaching agents. There are mainly two bleaching methods used in Europe today; elemental chlorine free (ECF) which utilizes chlorine dioxide, and totally chlorine free (TCF). To avoid decomposition of hydrogen peroxide, metal chelating agents such as ethylenediaminetetraacetic acid (EDTA) and diethylenetriaminepentaacetic acid (DTPA) may be used (see section 2.7 for more information regarding EDTA and DTPA)^{23,24}.

De-inking agents

²² CEPI 2014

²³ JRC 2015

²⁴ OECD 2014

De-inking agents are added to remove ink and toner from recycled paper such as newsprint, magazines and tissue paper. De-inking chemicals are e.g. sodium hydroxide, hydrogen peroxide, 2,2,2-nitrioltriethanol and ethoxylated surfactants^{23,24}.

Retention and drainage agents

Retention agents are added to improve retention of fillers, dyes and additional chemicals to the paper. In addition, retention agents also prevent chemical release into the water circuits. Retention agents create a positive charge on the paper surface that bind to other chemicals such as fillers²⁵. Draining agents improve water release from the pulp during drying. Examples of used retention and drainage agents are alum, sodium aluminate, starch products, gums, anionic and non-ionic polyacrylamides, polyethyleneimine, cationic polymers, colloidal silica and bentonite^{25,26,27}.

Fixatives

Fixatives are added to improve the absorption and function of applied chemicals to the fibre. Fixatives can be alum and cationic amines²⁶, such as [amines, N-C8-22-alkyltrimethylenedi-, acrylated, sodium salts].

Anti-foaming agents

Anti-foaming agents are added to destroy and prevent the formation of foam and bubbles formed in the fibre suspension during mechanical processing. Anti-foaming agents can be fatty acid ethoxylate, poly-oxi-ethylene, fatty acid derivatives, higher alcohols, phosphoric acid esters and vegetable oil products^{25,26,28}. Examples are [fatty acids, tall-oil, ethoxylated] and [alcohols, C13-15-branched and linear, butoxylated ethoxylated].

Dispersing agent

Dispersing agents are added to the fibre suspension to make disperse the suspension and avoid settlement of the dispersed fibres²⁸. An example of a dispersing agent is long chain alkyl sulphonates.

Wet end sizing agents

Wet end sizing agents are added to the fibre suspension to reduce the papers natural absorption capacity (i.e. make the material more hydrophobic). Sizing agents include starch (both modified and natural), rosin, glue, waxes and synthetic products such as alkyl ketene dimers (AKD) and polymers based on acrylic esters, maleic acid esters and acrylonitrile^{25,26,28}.

Biocides

Biocides are added to prevent microbial growth and slime (slimicides) formation in aqueous systems during paper production (material preservatives). Furthermore, biocides can also be used as a preservative (film preservatives) in paper coating and finishing applications. Biocides that are used are often strong oxidizing agents or bases such as sodium hypochlorite, organic bromine, sulphur and nitrogen compounds, quaternary ammonium compounds, chlorine dioxide and hydrogen peroxide^{26,27,29}.

Cleaners and surfactants

²⁵ CEPI 2014

²⁶ JRC 2015

²⁷ OECD 2014

²⁸ RISI 2017a

²⁹ ECHA 2017a

Cleaners and surfactants are added to remove contaminants and impurities to improve production- and paper quality. Examples of substances used for this purpose include orthophosphoric acid and acetic acid.

2.4.2 Functional chemicals in the final paper article

Functional chemicals are used in the paper production process to obtain specific characteristic of the final paper articles by influencing properties such as paper structure, strength, homogeneity, ink retention, gloss and colour^{30,31}.

Wet and dry strength agents

Wet and dry strength agents are added to improve the papers strength properties in wet and dry conditions, including burst strength, tensile strength, tear strength, and folding endurance. Modified starch is used for improving dry strength properties. To achieve wet strength properties, urea and formaldehyde polymers and epichlorohydrin polymers can be used^{30,31,32}. See Appendix B1 for details. Epichlorohydrin is specifically used in coffee filters and in tea bags.

Softeners

Softeners are added to improve the softness of paper. Softeners can be applied during the wet-end process or be sprayed onto the wet or dry web. Examples of a substances used are quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl and salts with bentonite³³.

Mineral fillers

Mineral fillers are added to obtain specific paper textures, surface properties and finish of the paper material. Mineral fillers can also function as pigment. Mineral fillers are used to improve printability properties, surface smoothness, opacity, brightness, gloss, ink receptivity and provide colour to the paper. Mineral fillers can substitute more expensive fibres to lower costs in production by filling in the space between fibres. Common mineral fillers and pigments are kaolin or clay, calcium carbonate, barium sulphate, limestone, talc, and titanium dioxide. In tissue making an anhydrous form of either natural or calcined calcium sulphate, derived from ground gypsum are used as a filler^{30,31,32,34}.

Starch

Starch is added to thicken the material and improve strength and rigidity of the paper. Starch improve finishing by causing the fibres to lay flat. Both native and modified starch can be used.

Native starch:

Carbohydrates extracted from agriculture raw materials such as potatoes, wheat and cereal.

Modified starch:

Native starch that have been chemically treated, generally by oxidation, to obtain suitable features as an additive^{32,34}.

³⁰ JRC 2015

³¹ OECD 2014

³² RISI 2017a

³³ Hagiopol & Johnston 2012

³⁴ CEPI 2014

Dyes

Dyes and pigments are added to obtain coloured paper and paperboards. Dyes are usually added to the fibre suspension, but can also be applied to the paper surface later. The choice of dye is highly dependent on the pulp and intended end-use of the paper article. Different dyes that can be used include basic dyes, direct dyes, acid dyes or mineral pigments. Dye fixatives, such as polyamine may also be added to enhance the absorption of the dye. Dyes are also used in printing inks.

Basic dyes:

Mainly used for mechanical and unbleached pulp due to the high acid content in the fibres. When used for ligneous pulp, alum may be added to optimise the colouring process. It is often used in the dyeing of lower quality and coarse paper grades such as newspaper, wrapping paper, kraft paper, boxboard and other inexpensive packaging papers. In addition, basic dyestuff produces brilliant colours with high tinctorial strength which make them suitable for calendar staining and surface colouring as well.

Acid dyes:

These colorants have no affinity for vegetable fibres, but can be used for both bleached and ligneous pulps. This is an advantage in producing a homogeneous appearance of the colour, as it does not mottle and have high solubility. However, the addition of fixatives and sizing agents such as rosin and alum is required for proper fixation. Due to the properties of acid dyes they release colour when wet and is therefore mostly used for construction grades e.g. heavy paper used for watercolour and crayon artwork paper. Acid dyes are most suitable for calendar staining or surface colouring.

Direct dyes:

Direct dyes have a high affinity for cellulose fibres and can be used for non- ligneous, ligneous and bleached pulps. They have great lightfastness and do not release colour when wet. Due to their properties, these colorants are useful for fine paper grades.

Pigments:

Inorganic pigments or organic pigments can be used as a colorant during the paper production process or as an additive in coating applications. Pigments are also used in the printing processes. These include azo compounds and phthalocyanine types, carbon black and mineral and earth pigments such as oxides, ochre and umbers^{35,36,37}. Examples of inorganic pigments are e.g. calcium 3-hydroxy-4-[(4-methyl-2-sulphonatophenyl)azo]-2-naphthoate (Pigment Red 57:1), 29H,31H-phthalocyaninato(2-)-N29,N30,N31,N32 copper (Pigment 15:3) and 2,2'-[(3,3'-dichloro[1,1'-biphenyl]-4,4'-diyl)bis(azo)]bis[N-(2,4-dimethylphenyl)-3-oxobutyramide] (Pigment Yellow 13) and an example of an organic pigment is carbon black. For more examples see Appendix B1.

Optical brightening agents

Optical brightening agents are added to make the paper appear whiter and enhance brightness. Different substances are used to achieve fluorescence and these can be added to both the fibre suspension as well as in coating applications. Common fluorescence substances belong to the class of stilbenes^{35,36,37} e.g. disodium 4,4'-bis[6-anilino-[4-[bis(2-hydroxyethyl)amino]-1,3,5-

³⁵ RISI 2017a

³⁶ JRC 2015

³⁷ OECD 2014

triazin-2-yl]amino]stilbene-2,2'-disulphonate and tetrasodium 4,4'-bis[[4-[bis(2-hydroxyethyl)amino]-6-(4-sulphonatoanilino)-1,3,5-triazin-2-yl]amino]stilbene-2,2'-disulphonate].

2.4.3 Coating chemicals

Paper and paperboards may be coated on one or both sides to improve or modify the surface properties of the paper. The coating systems are highly dependent on the required surface characteristics for each and every end applications and are usually comprised of water-based systems. For example, they typically consist of emulsion binders (carboxylated styrene-butadiene, styrene-acrylonitrile, or acrylic latexes) together with white pigments (white clay, chalk, and calcium carbonate) and various other additives applied on to the paper. The different grades of paper and paperboards can have different coating grades based on the quantity applied. Examples of this is lightweight coated paper (5-12g/m²/side) and coating grades in ranges below (ultra-lightweight coated) and above (medium- and high grade coated) including art paper (20 g/m²/side), machine-coated paper (25 g/m²/side) and boxboard (12-33 g/m²/side)^{38,39,40}.

Synthetic binders

Synthetic binders are added to bind the coating mixture tighter onto the paper and form films. These are often polymers,³⁹ such as butadiene-styrene rubber, 2-ethylhexyl acrylate, vinyl acetate, and butyl methacrylate.

Coating additives

Coating additives are added to improve the paper characteristics and finish. The additives used are dependent on the coating method and desired function of the paper article. Common additives are:

Surface sizing agents:

Added to make surface properties more hydrophobic. See “wet end sizing” for example.

Wet strength agents:

Improve wet strength of the paper.

Binders:

Optimise binding of pigments and dyes.

Mineral pigments:

Modify surface properties and enhance whiteness and brightness. Can also provide surface colouring. See above for examples.

Optical brightening agents:

Give the paper a whiter appearance. See above for examples.

Lubrication agents:

Lubrication during calendaring, often stearates e.g. calcium distearate and lithium 12-hydroxystearate.

³⁸ CEPI 2014

³⁹ JRC 2015

⁴⁰ OECD 2014

Anti-foaming agents:

Prevent the formation of bubbles during coating. See above for examples.

Biocides:

Can be used as preservative in the coating mixture 3, 2. Examples of biocides are: 2-octyl-4-isothiazolin-3-one and 5-chloro-2-methyl-4-isothiazolin-3-one.

Rheology modifiers

Rheology modifiers are added to modify and control the rheological properties of the coating chemical (mixture) to desired flow and viscosity⁴¹.

Starch

Starch is added to improve strength and stiffness properties of the paper^{38,40}.

Greaseproof or waterproof agents

Greaseproof or waterproof agents are added to introduce grease- oil- and water-repellent properties. Paraffin waxes and hydrocarbon waxes and silicone coatings are commonly used for this purpose. In addition, perfluorinated compounds (PFCs) based on fluorocarbon resins (FC) and perfluoropolyether (PEPE) can be used for impregnation and adhesive labels⁴². However, PFCs are commonly not used in Swedish production⁴³

⁴¹ Nordic Pulp&Paper 1993 (abstract)

⁴² JRC 2015

⁴³ Personal communication, Swedish paper industry 2017

Table 4. Overview of chemicals, examples of specific substances and their function. For details regarding the presence of a substance in paper articles, see Appendix B1.

Chemical category	Chemical group	Function	Chemicals and example of substances	Use in paper grades
Process chemicals	Bleaching agents	Increase brightness and cleanliness	Chlorine dioxide, oxygen, hydrogen peroxide and sodium hydroxide	Several types of white paper (e.g. tissue, newsprint, magazines etc.)
	De-inking agents	Removal of ink and toner from recycled paper	Sodium hydroxide, hydrogen peroxide, 2,2,2-nitritriethanol and ethoxylated surfactants	Papers articles made from recycled papers (e.g. tissue, newsprint, office papers, paperboard materials etc.)
	Retention and drainage aids	Improved drainage of water from the fibres while retaining fillers and other chemicals to the fibres	Alum, sodium aluminate, starch products, gums, anionic and non-ionic polyacrylamides, polyethyleneimine, cationic polymers, colloidal silica and bentonite	Most paper grades
	Fixatives	Improve absorption of dyes and chemicals to fibres	Alum and cationic amines, such as [amines, N-C8-22-alkyltrimethylenedi-, acrylated, sodium salts]	Most paper grades
	Anti-foaming agents	Decrease the formation of foam during manufacturing	Fatty acid ethoxylate, poly-oxi-ethylene, fatty acid derivates, higher alcohols, phosphoric acid esters and vegetable oil products. (e.g. fatty acids, tall-oil, ethoxylated and [alcohols, C13-15-branched and linear, butoxylated ethoxylated])	Most paper grades
	Dispersing agent	Reduce clumping of particles in the fibre suspension	Long chain alkyl sulphonates	Most paper grades
	Wet end sizing agents	Increase hydrophobicity of the paper	Starch (both modified and natural), rosin, glue, waxes and synthetic products such as alkyl ketene dimers (AKD) and polymers based on acrylic esters, maleic acid esters, acrylonitrile and fatty acids	Most paper grades
	Biocides	Prevent microbial growth and slime formation in machine circuits and as a preservative in coating mixtures	Sodium hypochlorite, organic bromine, sulphur and nitrogen compounds, quaternary ammonium compounds, chlorine dioxide and hydrogen peroxide	Most papers grades
	Cleaners and surfactants	Removal of contaminants and impurities	Orthophosphoric acid and acetic acid	Most paper grades

Functional chemicals	Wet strength agents	Improve strength in wet conditions	Urea and formaldehyde polymers	Most paper grades, particularly household papers
	Dry strength agents	Improve strength in dry conditions	Modified starch	Most paper grades
	Softeners	Improve paper softness	[Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with bentonite]	Sanitary and household papers
	Mineral fillers	Improve printability properties, opacity, smoothness, brightness, gloss and colour	Kaolin, clay, calcium carbonate, barium sulphate, limestone, talc, and titanium dioxide	Most paper grades
	Starch	Thickening and improve strength and rigidity	Native and chemically modified starch	Most paper grades
	Dyes	Give paper a certain colour and/or brightness	Basic dyes, direct dyes, acid dyes, mineral pigments (e.g. Calcium 3-hydroxy-4-[(4-methyl-2-sulphonatophenyl)azo]-2-naphthoate (i.e. Pigment Red 57:1), 29H,31H-phthalocyaninato(2-)-N29,N30,N31,N32 copper (i.e. Pigment 15:3) and 2,2'-[(3,3'-dichloro[1,1'-biphenyl]-4,4'-diyl)bis(azo)]bis[N-(2,4-dimethylphenyl)-3-oxobutyramide] (i.e. Pigment Yellow 13) carbon black)	Coloured papers from all paper grades, can also be used to get an even shade of brown paper materials (e.g. brown boards)
	Optical brightening agents	Enhance whiteness and brightness	Chemicals based the class of stilbenes (e.g. [disodium 4,4'-bis[6-anilino-[4-[bis(2-hydroxyethyl)amino]-1,3,5-triazin-2-yl]amino]stilbene-2,2'-disulphonate] and [tetrasodium 4,4'-bis[[4-[bis(2-hydroxyethyl)amino]-6-(4-sulphonatoanilino)-1,3,5-triazin-2-yl]amino]stilbene-2,2'-disulphonate]])	Newsprint, printing and writing paper, tissue and some coated paper grades (additive in coating mixture)
Coating chemicals	Synthetic binders	Binds the coating mixture tighter onto the paper	Butadiene-styrene rubber, 2-ethylhexyl acrylate, vinyl acetate and butyl methacrylate	Coated paper grades
	Coating additives	Improve the coating process, paper characteristics and finish.	See surface sizing agents, wet strength agents, binders, mineral pigments, optical brightening agents, lubrication agents, Anti-foaming agents and biocides	Printing and writing papers, paperboard materials, wrappings, sack krafts

	Rheology modifiers	Modify viscosity and consist of coating mixture	Cellulose ethers, clays, ionic polymers	Coated paper grades
	Starch	Improve strength and stiffness of the paper	Starch	Most paper grades
	Greaseproof and waterproof agents	Give paper grease- or water-repellent properties	Paraffin waxes and hydrocarbon waxes, silicone and perfluorinated compounds	Food and liquid wrapping/packaging papers and paperboards, baking paper
Other paper and board chemicals	Barrier coating agents	Barrier between package content and paperboard material	Aluminium together with ethylene vinyl alcohol (EVOH)	Food and liquid packaging boards
	Printing inks	Printing on paper and paperboard	Colourants (e.g. [pyrrolo[3,4-c]pyrrole-1,4-dione, 3,6-bis(4-chlorophenyl)-2,5-dihydro-])(red pigment), carbon black, UV/LED curing inks), binders (e.g. acrylates, nitrocellulose) and solvents (e.g. water, alcohols and mineral- and vegetable oils)	Printed paper articles, graphic and decorative (e.g. newsprint, cartonboard, tissue, office paper, magazines etc.)

2.4.4 Other paper and paperboard chemicals

Barrier coating agents

Barrier coating agents are often used in liquid board articles and other packaging papers. Barrier coating functions as a barrier between the paper and the content inside and prevents the migration of moisture, vapor, gases, oils, water or other liquids. Example of barrier coating agents are aluminium with ethylene vinyl alcohol (EVOH)^{44,45}. The barrier coating is usually applied by different lamination techniques.

Printing inks

Paper and paperboard materials are often manufactured for graphic and decorative purposes. Printing inks are, in general, complex mixtures of colourants, binders, solvents and other additives, designed to meet specific demands in respect to applied printing process and the intended end-use of the paper article to be printed (see Section 2.5 and Table 5 for details). Printing inks can be applied via several methods including flexography and gravure (solvent based and water-borne liquid inks), letterpress and offset (drying oil based inks), non-impact printing (water-borne jet-ink and laser printing) and roller coating. Additives are used to influence ink adhesion, rub resistance, gloss, slip and friction properties^{46,47}.

2.5 Inks and printing used in the paper industry

Table 5. Overview of printing inks used in the paper industry, grouped onto oil based inks, solvent based inks, water based inks and UV-curable inks. See Appendix B1 for more substances.

Component in printing ink	Drying oil based inks	Solvent based inks	Water-borne inks	UV-curable inks
Binder	Natural modified rosins and hydrocarbon resins	Nitro-resins and polyvinylbutyral (PVB)	Acrylates	Acrylated prepolymers and cycloaliphatic epoxides
Solvent (if used) (quantity %)	Mineral- and vegetable oils such as soybean oil and extracts (petroleum), deasphalted vacuum residue solvent	Isopropanol, ethanol, esters and ketones (> 30%)	Water (<15%)	Non
Pigment	<i>Inorganic:</i> Black (carbon black) <i>Organic:</i> Cyan, magenta and yellow e.g. carbon black, [calcium 3-hydroxy-4-[(4-methyl-2-sulphonatophenyl)azo]-2-naphthoate] (Pigment Red 57:1), [29H,31H-phthalocyaninato(2-)-N29,N30,N31,N32 copper] (Pigment blue 15:3) and [2,2'-[(3,3'-dichloro[1,1'-biphenyl]-4,4'-diyl)bis(azo)]bis[N-(2,4-dimethylphenyl)-3-oxobutyramide]](Pigment Yellow 13)	Organic pigments and inorganic pigments e.g. [pyrrolo[3,4-c]pyrrole-1,4-dione, 3,6-bis(4-chlorophenyl)-2,5-dihydro-](red pigment) and carbon black	Organic pigments and inorganic pigments e.g. [pyrrolo[3,4-c]pyrrole-1,4-dione, 3,6-bis(4-chlorophenyl)-2,5-dihydro-](red pigment) and carbon black	Organic pigments and inorganic pigments e.g. [pyrrolo[3,4-c]pyrrole-1,4-dione, 3,6-bis(4-chlorophenyl)-2,5-dihydro-](red pigment) and carbon black

⁴⁴ RISI 2017a

⁴⁵ JRC 2015

⁴⁶ OECD 2014

⁴⁷ EUPIA 2017

Additives	<i>In inks:</i> Kaolin, alkyds, oils with different viscosity and polarity. <i>Dampening solution used in the printing process:</i> pH-agents (acids and their salts; organic acids or phosphoric acid), colloids (cellulose or sugar derivatives), surfactants and biocides.	Wax, anti-foaming agents, silicones and plasticizers, fillers	Biocides, wax (polyethylene). anti-foaming agents, dispersing agents, glycols, fillers (e.g. titanium dioxide, calcium carbonate)	Photo-initiators, wax, silicones, polysiloxanes and stabiliser
Paper material and/or paper article	Newspaper, magazines, advertising material, direct mail and containers for cosmetics and foods.	Plastic film coated material (e.g. containers for milk and other paperboard materials)	Paperboards and packaging material (e.g. paper well pap, cups, paper bags, liquid boards), self-adhesive labels (paper and plastic)	Self-adhesive labels (paper and plastic) and paperboard materials and containers for food

Printing ink is used on multiple paper articles, including packaging of consumer items, illustrations on magazines, newsprint, posters and tissue. In general, printing inks can be divided into four categories; drying oil based inks, solvent based inks, water-borne inks, UV-curable inks (Table 5). The end-use decides which type of printing ink that is most suitable. However, all printing inks have the same three key ingredients; binders, solvent and pigments. In addition, printing inks also contain facilitating additives to improve the print (see Table 5).

Moreover, a finishing application (e.g. lamination or lacquer) is often applied to the paper or paperboard to protect the printed surface.

The printing process is chemical intensive (see Appendix B1) with various chemical compositions of printing inks^{48,49}.

2.6 Presence of contaminants and impurities in paper

Substances are added in paper or used in associated processes in a variety of the material lifecycle stages, e.g. in pulp and paper production and paper article manufacturing. However, Non-Intentionally Added Substances (NIAS) can also be present (e.g. impurities in additives used or residues from process additives). Once paper and paperboard materials are converted into final paper articles, substances are also added through use of printing inks and adhesives. Final paper articles are distributed into use (i.e. paper consumption), where substances may be added as contamination in use of paper articles (e.g. mineral oils in tissue paper)⁵⁰ or as a cross contamination in waste collection. Most of the paper lifecycle stages depicted in Figure 6 may also have additional input of substances from e.g. imports of paper for conversion or direct consumption. If purity of substances intentionally used in production and manufacturing is not 100%, which often is the case, impurities may also be present. For example, mineral oils used in paper printing may contain aromatic hydrocarbons as impurity^{51,52}. Impurities may also result from polymerisation by-products or break down products of the additives used.

In addition, contamination may arise from use of recycled paper in paper production. Substances not currently in use may still be present in paper for recycling and, if not

⁴⁸ SVEFF 2003

⁴⁹ Personal communication, FlintGroup 2017

⁵⁰ Pivnenko et al. 2013

⁵¹ Pivnenko et al. 2015

⁵² Biedermann et al. 2010

completely removed, be transferred into newly manufactured paper materials and products⁵³. As previously mentioned, material imports of paper from other countries (e.g. for direct use or paper recycling) may result in presence of impurities if production standards between the two trading partners do not match. For example, lenient environmental and production standards in emerging economies may result in presence of furans and dioxins in paper due to use of elemental chlorine in the pulp production⁵¹.

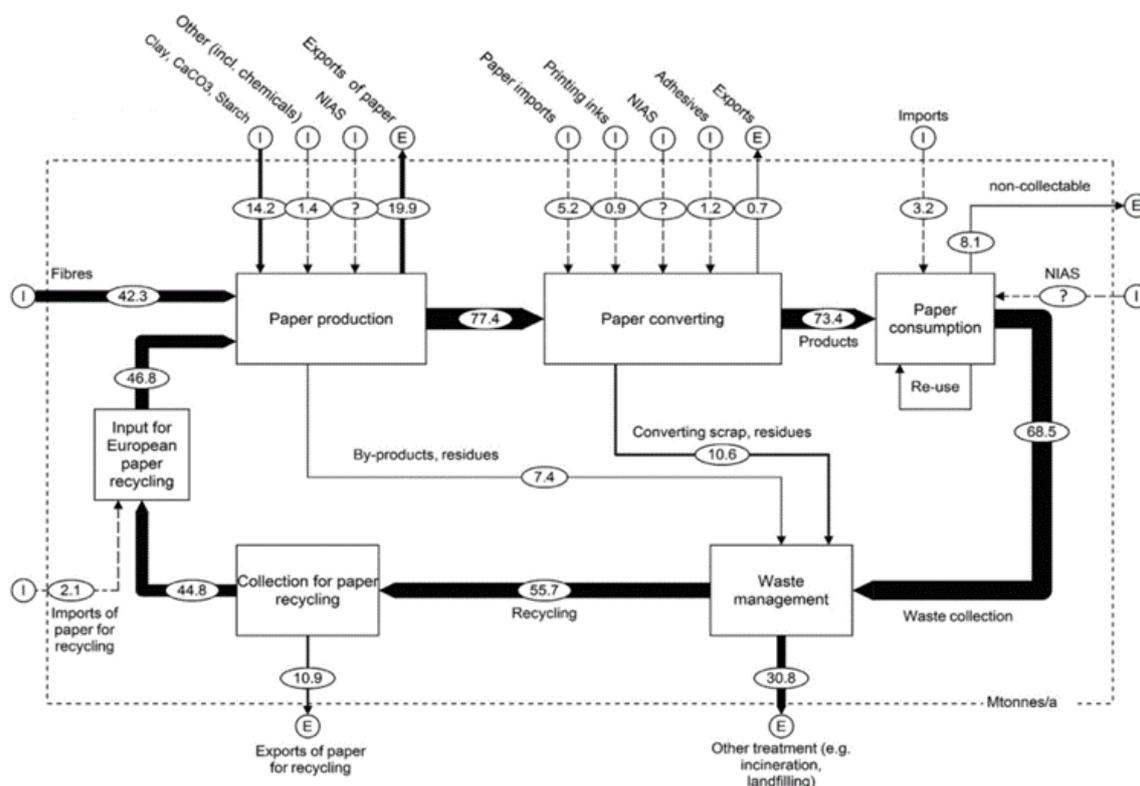


Figure 6. Schematic representation of the European paper material loop. Arrows represent flows of materials (e.g. pulp, paper, additives) in Mtonnes for the year 2012. Dotted lines indicate lifecycle stages where chemical substances are introduced. The lifecycle stages are 1) paper production 2) paper converting 3) paper consumption 4) waste management 5) collection for paper recycling and 6) Input for European paper recycling. I: Imports; E: Exports; NIAS: Non-Intentionally Added Substances (reprinted with permission from Pivnenko et al 2015⁵¹).

2.7 Trends within the paper industry

Substances in paper articles within the EU and EEA are regulated by various legislation, such as Regulation EC (no) 1907/2006 (REACH), EU (no) 528/2012 or EC (no) 1935/2004. See Section “Definitions and abbreviations” for the full names of the mentioned regulations.

These three regulations are all EU regulations, so it is possible that paper articles produced in third countries may not comply with these regulations. However, companies that place paper articles on the European market shall comply with EU regulations. The regulations are dynamic so more and more substances are regulated and will therefore, with time, disappear from the market. For the paper industry, there is a possibility that forbidden substances exist in paper articles due to usage of recycled pulp; however, there is a natural phase-out process

⁵³ Pivnenko et al. 2016a

as fibres only can be recycled a certain number of times⁵⁴ and need to be reinforced with either more recycled fibres or with virgin fibres

New classification of substances can also drive changes e.g. the proposed classification of titanium dioxide as a substance suspected of causing cancer⁵⁵ has caused the paper industry to evaluate potential options⁵⁴.

Consumer demands have also pushed the paper industry towards more environmentally friendly processes. One example is the bleaching process that used to be based on chlorine and chlorine substances as bleaching agents. However due to consumer concerns regarding the release of organochlorine compounds to the environment, elemental chlorine free (ECF) and totally chlorine free (TCF) bleaching processes were developed (see Section "Definitions and abbreviations").

These consumer demands have led to that ECF technology is now the world dominating bleaching process. In general, ECF and TCF are the only two technologies that are used within the EU⁵⁶. However, it is considered a risk that paper articles produced in a third country can have been bleached with elemental chlorine.

In addition, it is possible to replace two chelating agents (EDTA and DTPA), which are used in the pulping process to re-mobilise metals and reduce odour in mechanical pulp, for more environmental friendly and biodegradable alternatives. Certain ecolabel organisations, e.g. Blue Angel and Nordic Swan, promote this development. Both Blue Angel and Nordic Swan have some restrictions on EDTA and DTPA in paper articles⁵⁷. However, no chelators available displaying the same or equivalent good properties as EDTA and DTPA when it comes to efficiency in bleaching processes and preventing flavour and odour in different types of paper and board packaging materials⁵⁸.

Other substances that are no longer commonly used in Sweden due to consumer demands are PFAS (can be used in greaseproof coatings) and bisphenol-A (BPA, used in thermo-paper and food containers)⁵⁴. In addition, BPA will not be allowed, from 2020, in thermo-paper in higher concentrations than 0,02 % by weight⁵⁹. However, concerns about BPA substitutes (e.g., bisphenol-S, BPS) have been expressed⁶⁰.

Another drive for change is price increases for raw materials. For example, mineral oil (used in printing inks) is on its way to be replaced with new technology as well as digitalisation⁵⁴. In addition, due to consumers and food safety the printing ink industry work towards safer chemistry by choosing water-based inks when possible as well as replacing smaller molecules with bigger molecules as these does not migrate as easily. It is unlikely that the bigger replacement molecules would degrade during normal use, since chemicals are selected partly on stability criteria.

⁵⁴ Personal communication, Swedish paper industry 2017

⁵⁵ ECHA 2017b

⁵⁶ Paperonline 2017d

⁵⁷ Sankari & Aksela 2011

⁵⁸ Staffas et al. 2013

⁵⁹ EC (no) 1907/2006, Annex XVII, post 66

⁶⁰ Pivnenko, K et al, 2018

3 Result and Discussion

3.1 Identification of relevant paper and paperboard on the Swedish market

In this section, the origin of paper articles placed on the Swedish market was identified. The origin of paper article played a crucial role in the development of the prioritisation model of substances presented in Section 3.3. In addition, in this section (Section 3.1) paper consumption and exposure scenarios for the various paper grades were also identified. This information was used to develop a prioritisation model to identify relevant paper grades (Section 3.1.3).

3.1.1 Origin of paper and paperboard on Swedish market

Paper and paperboard articles on the Swedish market were divided into the earlier mentioned paper grades (see Section 2.2). The production country/region of the paper and paperboard varied between the sub-grades. From the figure below (Figure 7) it was possible to state that the domestic production of paper articles was dominant. The only paper grade where domestic produced articles were relatively uncommon was the sub-grade other paper and board. This sub-grade was, as earlier mentioned, very heterogeneous and it was possible that the origin of the produced articles in this sub-grade varied on item-to-item basis.

Due to limited data availability, it was not feasible to separate the EU data into separate countries. Using consumption data, the share of domestic production was lower than imports for Case materials and Other paper and board only (Figure 7), Sweden is one of the largest producers of paper and board in the EU. Therefore, Sweden can be assumed to be one of the largest producing countries for specific product types as well. This was considered likely in the case of case material but it was also considered possible in the case of other paper and board. It was also possible to state that in general the import from countries in the category “outside the EU excl. Norway”, was relatively small in comparison with the import from the EU or domestic production.



Figure 7. Origin of the paper material grouped in paper grades or paper sub-grades. The consumption distribution of the Swedish market, in percentage, between the four regions or origins; Sweden, Norway, the EU excl. Sweden and outside the EU excl. Norway.

The main regions from outside the EU that contributed to paper articles in Sweden were countries within Europe but not within the EU, such as Norway and Turkey. Outside Europe, Asia with China was the largest contributor. Asia was the world dominating paper producing region; however, on the Swedish market they contributed to less than 1%.

The foremost contributor was Norway, where Sweden imported mechanical paper, newsprint and case material as the largest fractions. Norway, as well as e.g. Iceland, belonged to EEA,

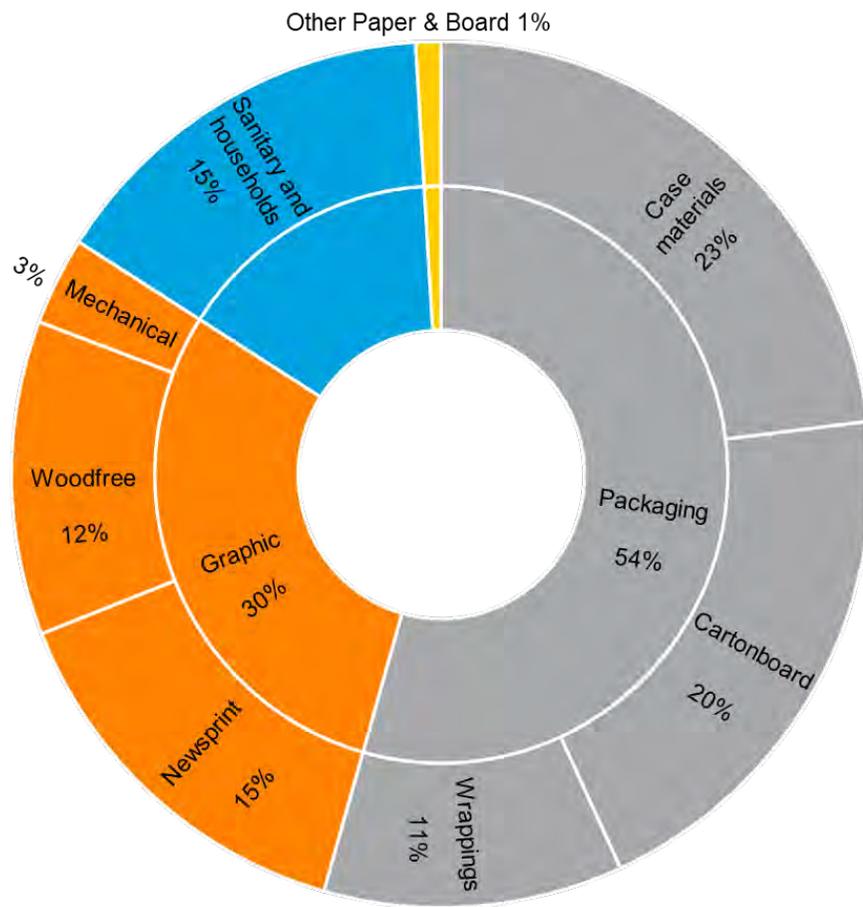
hence also followed the REACH Regulation. The small contribution from Asia mainly consisted of the paper grades other paper and board and woodfree paper. For delimitations regarding statistical data, see Appendix A2.

3.1.2 Consumption of paper and paperboard in Sweden

The paper consumption of sub-grades in Sweden and the EU was very similar. In percentage, the division between the various categories were on the Swedish market 54% of packaging papers, 30% of graphic papers, 15% of sanitary and household papers and 1% of other papers and board (Figure 8A)

When comparing the paper articles consumed in Sweden with the consumption in the EU, clear similarities could be found between the different markets (Figure 8A and B). The main fraction for both Sweden and the EU consisted of packaging, the second largest fraction was graphic paper, third largest paper grades was sanitary and household paper and the smallest fraction was other paper and board. The major difference concerned cartonboard that had a 12% higher quantity in Sweden compared to the EU average. Other sub- grades that were slightly larger in Sweden than in the EU were newsprint (7%), sanitary and household (6%), and wrappings (7%). Case materials was the largest fraction under packaging both for Sweden and the EU, but the consumption was 11% higher in the EU.

A) Paper & Board on the Swedish market 2016



B) Paper & board consumption in EU 2016

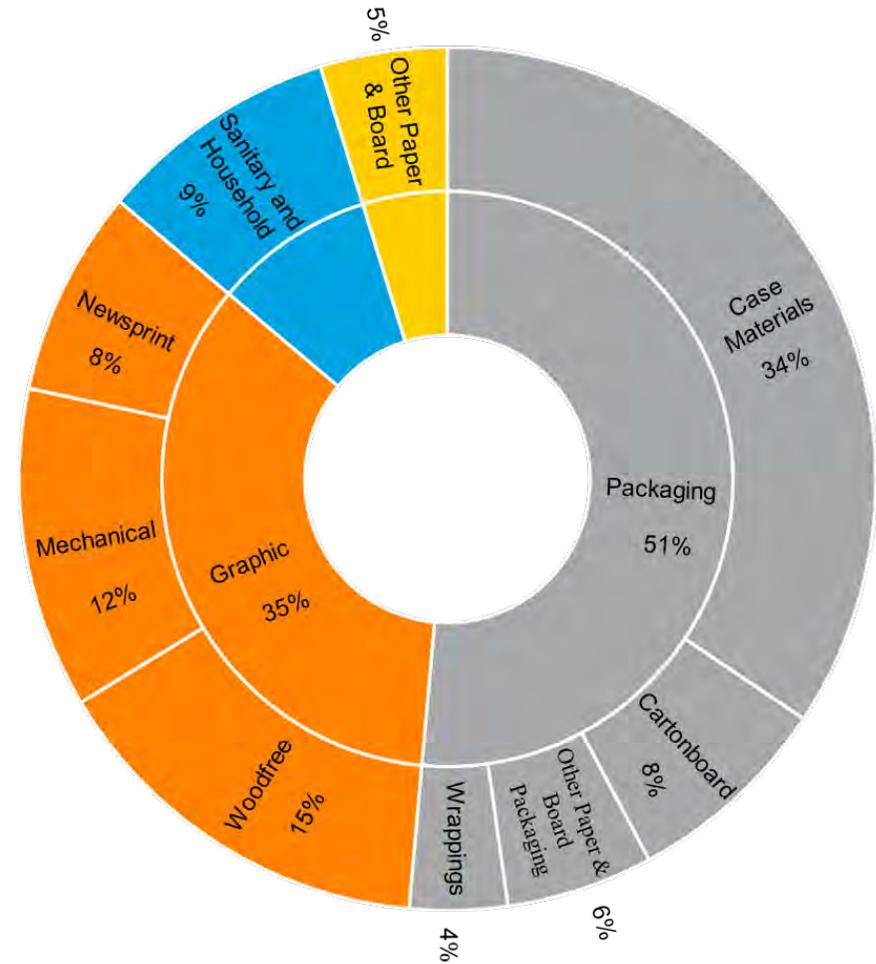


Figure 8. Consumption distribution. It was a similar distribution of paper and paperboard materials on the Swedish market (A) as on the EU market (B).

3.1.3 Consumer exposure of paper and paperboard

To be able to prioritise among the various sub-grades, exposure scenarios were developed according to Appendix A1.

First, exposure scenarios were compiled for the two groups; young children (<3 years old) and older children and adults (> 3 years old), see Table 6 and Table 7.

From the exposure scenarios (Table 6 and Table 7) the following conclusions were drawn:

- Wrappings and cartonboard were considered to be particularly relevant for consumer exposure as they could give rise to direct dermal exposure and indirect oral exposure to chemicals via food and drinks.
- Sanitary and household papers were also considered particularly relevant because chemical exposures could occur through direct skin contact and through direct contact with mucous membranes.
- Newsprints, mechanical paper and woodfree paper were considered less relevant since dermal exposure was the only main exposure pathway.
- Case materials, which were mainly used for corrugated boxes, transport packaging and storage were considered least relevant as such articles were not used in everyday life to the same extent as articles made from the other materials.
- Smaller children (< 3 years old) were considered extra vulnerable to chemical exposure due to mouthing behaviour.

Table 6. Consumer exposure scenarios for children, adolescents and adults

Material	Example articles	Exposure pathways				Daily exposures		
		Skin contact	Contact with mucous membranes	Oral exposure through mouthing	Oral exposure via food and drinks	Frequency	Duration (minutes)	Total daily exposure (minutes)
Newsprint	Newspapers	Yes	No	No	No	3	10	30
Mechanical paper	Consumer magazines, catalogues, advertising material, book paper	Yes	No	No	No	5	10	50
Woodfree paper	Office paper, book paper	Yes	No	No	No	5	10	50
Sanitary and household paper	Toilet paper, house hold paper, facial tissues, sanitary towels, napkins	Yes	Yes	No	No	10	1	10
Wrappings	Sack kraft, wrapping kraft, grease proof paper	Yes	No	No	Yes	2	1	2
Case materials	Corrugated boxes, transport packaging, storage and article display	Yes	No	No	No	<1	1	1
Carton board	Containers for food, liquids and cosmetics	Yes	No	No	Yes	5	1	5
Other papers and board	Insulating paper and paperboard, cigarette paper, envelope paper, gypsum liners, felt paper, filter paper, wallpaper	Other papers and board consists of too large variety of articles to develop exposure scenarios that are specific for the whole category						

Table 7. Consumer exposure scenarios for small children (0-3 years).

Material	Examples articles	Exposure pathways				Daily exposures
		Skin contact	Contact with mucous membranes	Oral exposure through mouthing	Oral exposure via food and drinks	
Newsprint	Newspapers	Yes	No	Yes	No	Daily oral and dermal exposure through mouthing of paper and paperboard articles: 26 minutes (USEPA 2008)
Mechanical paper	Consumer magazines, catalogues, advertising material, book paper	Yes	No	Yes	No	
Woodfree paper	Office paper, book paper	Yes	No	Yes	No	
Sanitary and household paper	Toilet paper, house hold paper, facial tissues, sanitary towels, baby nappies, napkins	Yes	Yes	Yes	No	Estimated daily exposure to sanitary paper from contact with mucosal membranes: 16 minutes
Wrappings	Sack kraft, wrapping kraft, grease proof paper	Yes	No	Yes	Yes	
Case materials	Corrugated boxes, transport packaging, storage and article display	Yes	No	Yes	No	
Cartonboard	Containers for food, liquids and cosmetics	Yes	No	Yes	Yes	
Other papers and board	Insulating paper and paperboard, cigarette paper, envelope paper, gypsum liners, felt paper, filter paper, wallpaper	Other papers and board consists of too large variety of articles to develop exposure scenarios that are specific for the whole category				

Both the results from Table 6 and Table 7 were graded 1-6 as well as the quantity of the various sub-grades on the Swedish market. These numbers were used in the material prioritisation model (Figure 9).

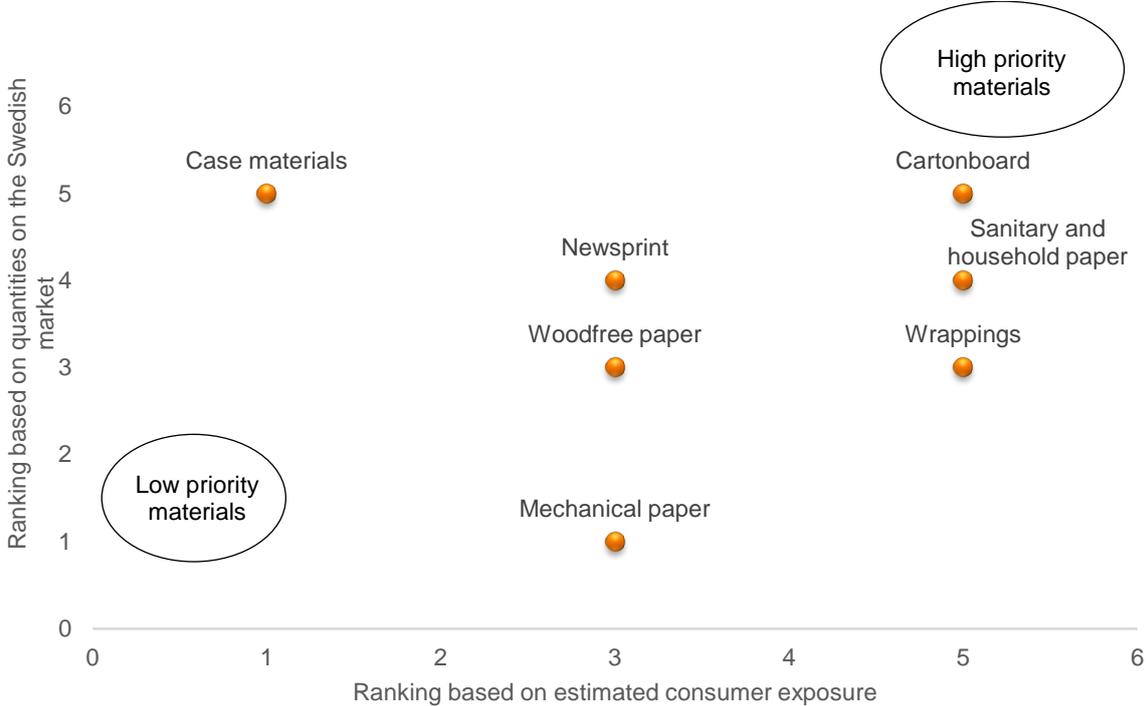


Figure 9. Prioritisation of paper sub-grades based on quantities on the Swedish market and estimated consumer exposure. The highest ranked sub-grades were Cartonboard followed by Sanitary and household paper and Wrappings. Lower ranked sub-grades were Newsprint, Woodfree paper, Case materials and Mechanical paper.

By combining the information about quantities of different sub-grades on the Swedish market and the estimation of consumer exposure, it was possible to prioritise the sub-grades (Figure 9).

It was concluded that the only sub-grade that was of less interest was other paper and board, due to its low quantity (1%) on the Swedish market in comparison with the other sub-grades.

3.2 Impact of recycling

During the project, it was found that use of recycled paper in paper production was considered an integral part of global and European paper industry. It was essential for the industry to get the addition of end-of-life paper and paperboard that resulted in recovery of paper for recycling of around 55% on the global scale⁶¹. While overall, roughly half of the European paper industry raw material needed to be derived from recycled paper, use of recycled paper could differ from region to region and from country to country. For example, recovery of paper in Africa was approximately 25%, while data for Europe suggested more than 70% of paper recovered for recycling^{60,62}. In addition, different paper grades could use more or less recycled fibres, depending on quality of recycled paper and quality specifications of intended paper articles. On the other hand, if substances in the end-of-life paper were not completely removed during paper re-processing, contamination of newly manufactured paper could

⁶¹ FAO 2015
⁶² CEPI 2016

occur^{63,64}. As mentioned in Section 2.6, use of recycled paper in paper production and paper article manufacturing could result in addition of substances (e.g. potential contaminants) to final articles. Since identification of specific substances, their sources and amounts of substances introduced through paper recycling was rather complex, knowledge of the recycled fibre content in paper could be used as an estimate for probability of contaminant presence⁶⁵. Hence, the aim of this section was to provide an overview of recycled fibre content in paper grades produced in Europe and Sweden.

Secondary raw materials (i.e. end-of-life paper and board collected for recycling) were important sources of feedstock for the European paper production industry. Driven by economic incentives and potential environmental benefits, European paper producers had increased the share of recycled paper in paper and paperboard production. As evident from Figure 10, the historical use of recycled paper by the European paper industry had shown a steady increase from early 1990s up until the year 2010. On the other hand, as also illustrated by Figure 10, the increase in recycled paper use had led to a decrease in virgin pulp consumption. There was a clear correlation between use of recycled paper and consumption of virgin pulp in European paper production (Figure 11). However, a combination of reduced paper consumption across Europe⁶³ and deterioration of paper fibre quality resulting from multiple cycles of material in the European paper cycle⁶⁶ led to a gradual stabilisation of recycled paper use rates (and virgin pulp consumption) from the year 2010 and onwards (Figure 10).

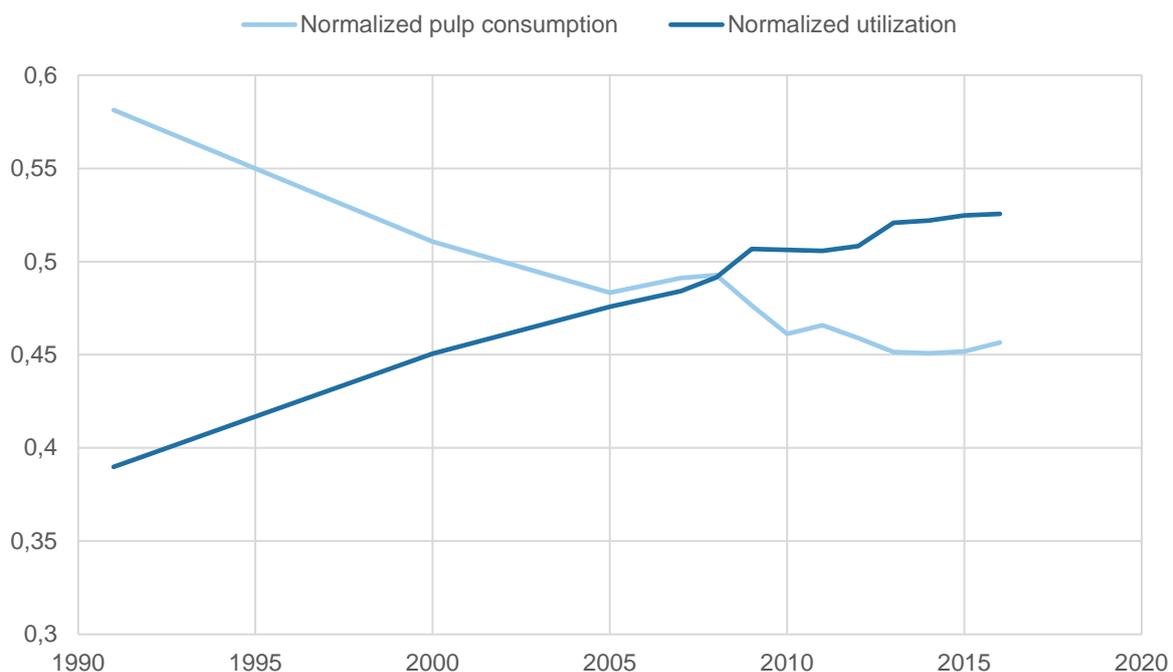


Figure 10. Historical development of pulp consumption and recycled paper utilisation in the European paper production (1991-2016). Values were normalised per historical paper production amounts.

While publicly available statistics on recycled paper collection and utilisation were provided by e.g. CEPI, the actual amounts of fibres ending up in paper and paperboard materials based

⁶³ Pivnenko et al. 2016a

⁶⁴ Pivnenko and Astrup 2016

⁶⁵ CEPI 2016

⁶⁶ Iveta et al. 2011

on secondary raw materials could differ. The amount of fibres depended on the efficiency of recycling process, which in its turn depended on the quality of paper fibres in the input material and the quality requirements of the final paper article^{67,68}. While reliable data on efficiency of paper recycling process was sparse, some estimates were available in the literature⁶⁷. By combining the estimated efficiency of paper recycling process and utilisation rates of recycled paper in Europe in general, or Sweden in particular, the content of recycled fibres in selected paper materials could be estimated. The statistics on recycled paper utilisation for a specific paper material and paper recycling efficiency represented average values, further variations in recycled fibre content within geographical region (e.g. Europe) or a country (e.g. Sweden) could occur.

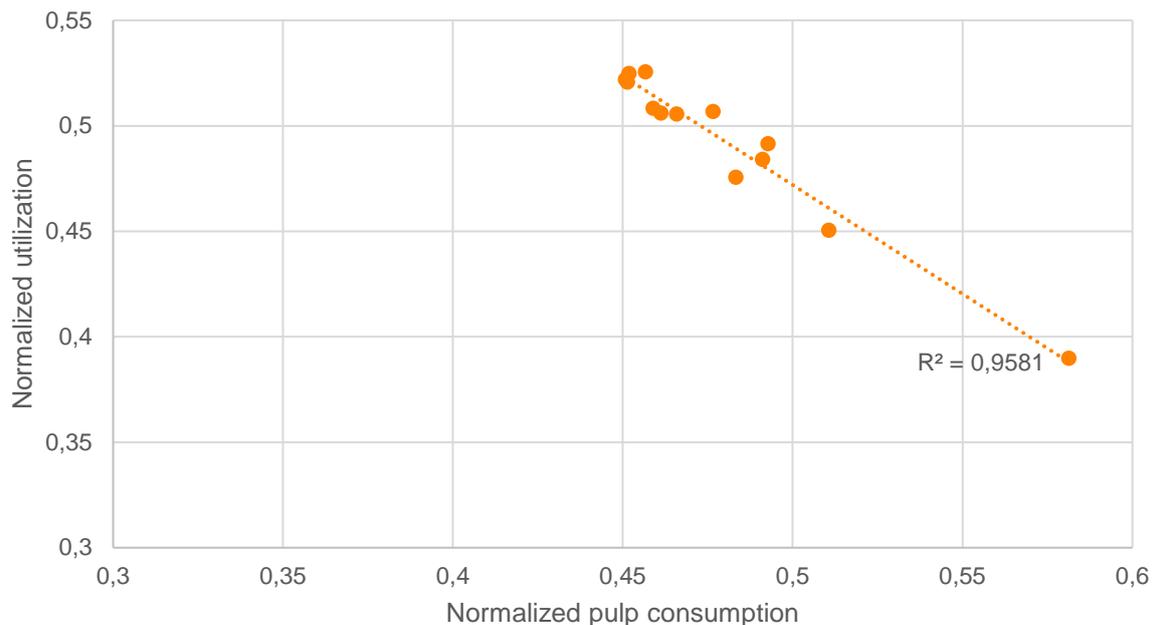


Figure 11. Correlation between pulp consumption and utilisation of recycled paper in the European paper production (1991-2016). The figure shows a clear correlation, $R^2 = 0,9581$. Values were normalised per historical paper production amounts.

The main share of paper and paperboard consumed in Europe was collected as paper intended for recycling. In 2016, of the 77,4 Mtonnes of paper consumed in Europe, more than 72% (56,4 Mtonnes) were collected for recycling. Some of the paper collected for recycling was exported, while some paper was also imported for recycling in Europe.

Most of paper imported for recycling into the EU came from other European countries (e.g. Norway and Switzerland), and overall constituted a negligible fraction (approximately 4%) of the total utilisation of recovered paper. Once amounts of paper utilised for recycling were known and efficiency of paper re-processing was estimated, the overall recycled fibre content could be calculated. As data presented in Figure 12 suggested, paper and paperboard materials produced in Europe had 46% content of recycled fibres, on average. Recycled fibre content in paper and paperboard produced in Sweden was substantially lower. On average, approximately 10% of fibres in Swedish paper and paperboard articles derive from recycled paper, while the remaining fibres derived from virgin raw materials (e.g. wood). This primarily resulted from the fact that while Sweden represented more than 10% (10,1

⁶⁷ Ervasti et al. 2016

⁶⁸ Pivnenko et al. 2016a

Mtonnes) of the European paper production, less than 20% of the total production was consumed within the country and the rest was exported. Even though more than 50% of paper for recycling used in Sweden came from imports (primarily from other EU countries), when compared to the volumes of paper and paperboard production, imports into Sweden of paper for recycling were negligible (less than 8%). These two factors, coupled with reliability of virgin pulp supply, resulted in rather limited use of recycled fibres in paper production and hence, low (average) fibre content in paper and paperboard produced in Sweden.

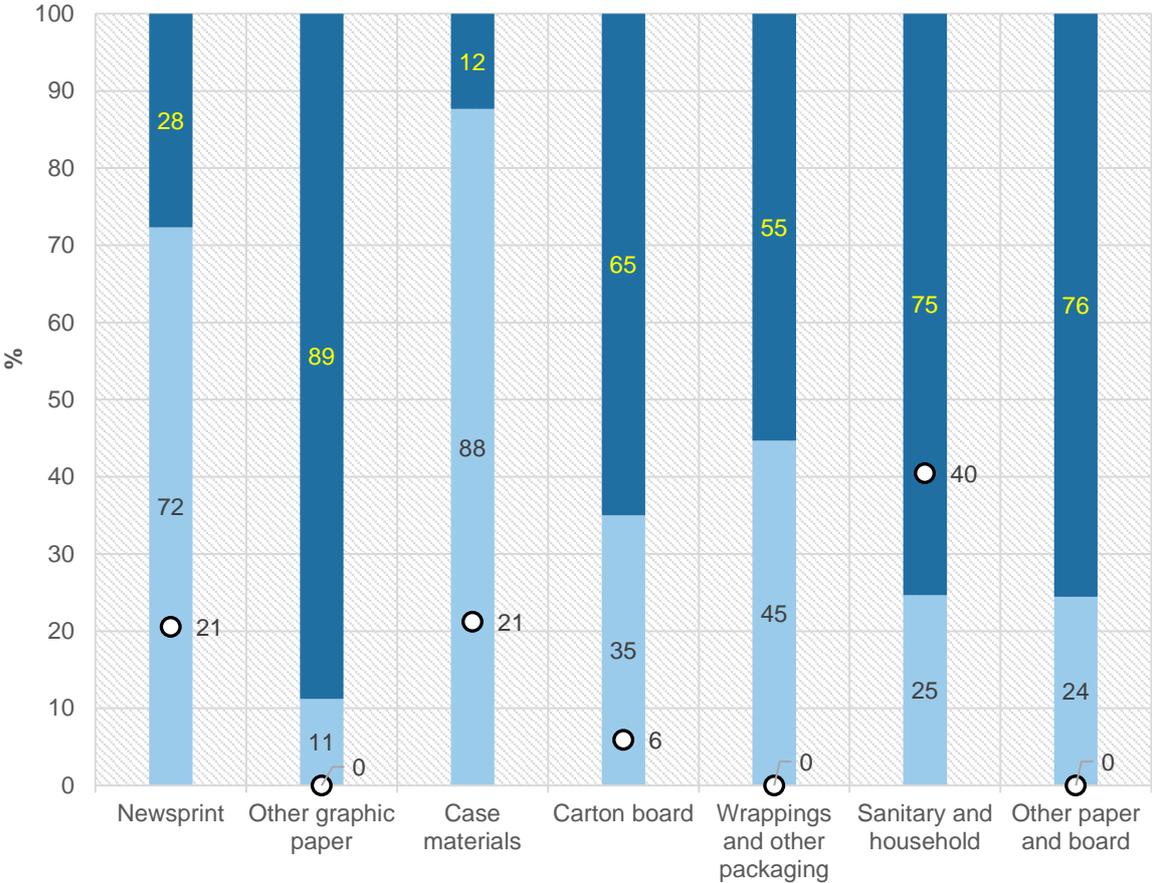


Figure 12. Comparison of distribution between recycled (light blue) and virgin fibre (dark blue) content in seven paper and paperboard categories for Europe (stacked columns) and Sweden (markers recycled fibre content).

Figure 12 presents distribution of virgin and recycled fibre content in the seven paper and paperboard product categories produced in Europe and Sweden. It was evident that across Europe, “newsprint” and “case materials” were two categories with the highest share of recycled fibre (>70%). They were followed by “wrappings and other packaging”, “cartonboard”, “sanitary and household” and “other paper and board”. The lowest recycled fibre content was in “other graphic paper”, potentially resulting from high quality requirements (e.g. fibre length, brightness) for articles in this category (e.g. magazines). Compared to the European average values, shares of recycled fibres in most of the product categories produced in Sweden are considerably lower (Figure 12 and Figure 13). For example, “case materials” produced in Europe contained more than 80% of recycled fibre, while same product category produced in Sweden contained approximately 20%. Use of

recycled paper for production of “other graphic paper”, “wrapping and other packaging”, and “other paper and board” in Sweden was almost negligible. Sanitary and household paper (e.g. toilet paper and kitchen towels) was the only product category with higher recycled fibre content in Swedish articles (approximately 40%), when compared to the European average (approximately 25%). While sanitary and household paper represents less than 4% of the Swedish paper production (by mass), most of the articles within this product category were domestically consumed. One potential reason for the high share of domestic consumption of sanitary and household papers is that those articles are bulky and thus inefficient to transport over long distances.

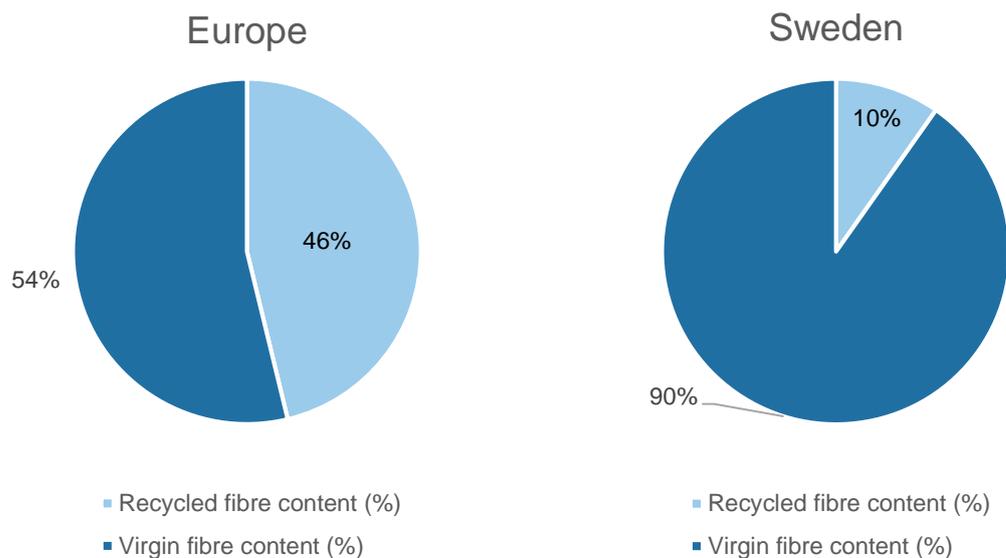


Figure 13. Distribution of recycled and virgin fibres in paper and paperboard produced in Europe and Sweden in the year 2016

3.2.1 Impact of recycling on the Swedish market

Substances contained in paper and paperboard articles in the end-of-life phase are not completely removed in the recycling process. For example, bis(2-ethylhexyl) phthalate (DEHP), a phthalate plasticizer commonly found in a variety of paper and paperboard articles⁶⁹, was reduced in concentration by only 20% following a paper recycling process⁷⁰.

The actual removal efficiency for a substance could vary depending on employed recycling technology, process specifications and levels of contamination. Hence, increased recycling rates (i.e. recycled fibre content of paper articles) also led to an increase in probability of substances transferred into articles based on recycled paper and paperboard and even accumulation and increase of substance amounts with growing number of material cycles⁷¹. The fact that recycled paper was used less in Sweden when compared to the European averages (see Figure 13), reduced the probability of transferring substances from paper for recycling into final articles manufactured within the country. Sanitary and household paper was the only product category where use of recycled paper in Sweden was higher than European average (see Figure 12), requiring additional attention in terms of potential

⁶⁹ Pivnenko et al. 2016b

⁷⁰ Jamnicki et al. 2012

⁷¹ Pivnenko et al. 2016a

contamination. The types of substances potentially ending up in recycled paper depended, among other (e.g. removal efficiency, source of paper for recycling), on the grade of paper for recycling used.

For example, household and sanitary paper articles manufactured in Europe contained primarily high grades of paper for recycling⁷². High grades could be assumed to have limited presence of substances, since they do not contain printed matter, corrugated and kraft or mixed paper grades. However, newspapers and magazines, as well as mixed paper grades, could also be used in household and sanitary paper production to a lesser extent.

In addition, due to potential differences in production specifications and environmental standards, imports of paper for consumption or recycling could result in introduction of contaminants into local paper production cycle. In case of paper articles, but also end-of-life paper for recycling, most of imports into Sweden originate from another European (primarily the EU) country. Hence, most of the material eventually used in domestic production was regulated either through Swedish or European legislations.

3.3 Identification and prioritisation of substances in paper articles

This section aimed to identify substances potentially used in paper production or present in final paper and paperboard articles. Identification was based on literature review and combined a variety of literature sources, described in detail in Appendix A1. Number of substances derived from each of the information sources differed and varied between 50 (Norwegian Product Register, NPR) and more than 7000 (European Printing Inks Association, EUPIA). Furthermore, reviewed information sources were prioritised, in accordance to their relevance to the overall aim of the present project. Finally, use of chemicals in selected paper and paperboard articles was discussed and examples provided.

3.3.1 Substances used in the paper industry

Combining the information sources described in Appendix A1 resulted in identification of the total of 17,656 entries (see Appendix B1 for details). Most of the entries concerned single substances, while some either concerned substance mixtures or groups. For simplicity, entries in lists or data sources concerned in this study (Table 8) will in this text be referred to as “substances”.

The majority of substances (>90%) had CAS numbers, while for some substances the CAS numbers were not provided in the original information and data source. All the data sources identified in this section were attributed to either paper or pulp, printing or other industries (see below for explanation). As Table 8 indicated, most of the substances (71%) were associated with printing industry, while approximately 18% were potentially used in the paper and pulp industry. Almost 11% of substances were associated with “other” industrial sectors (e.g. use of adhesives in gluing), or the source of a substance was unknown (impurity or contamination). Chemical impurities and contaminants could originate from a variety of sources, as discussed in Section 2.6. Impurities could derive from e.g. substances present in raw materials used in paper article manufacturing. In this project, it was considered that the presence of contaminants in paper usually resulted from incomplete chemical reaction,

⁷² Pivnenko and Astrup 2016

degradation of primary substances, residual content of process additives or through use of recycled paper in paper and paperboard production⁷³.

Industrial sector “other” in Table 8, referred to industries other than paper and pulp or printing. As an example, analytical results from experimental literature provided identification (or quantification) of substances in paper and paperboard samples, however presence of those substances could arise from use in paper and pulp production, printing, other industrial processes (e.g. adhesive application) or contamination. Hence, substances from experimental literature were assigned to all three industrial sectors. Similarly, substances registered by the European Chemicals Agency (ECHA) could be used in paper and pulp production, paper printing or other processes resulting in presence of those substances in the final paper and paperboard articles. Since a single substance from the same information source could be assigned to more than one industrial sector, total number of substances in Table 8 was greater than 17,656 initially mentioned.

Table 8. Distribution of number of substances by industrial sector. Including duplicate values.

Industrial sector	Information source	Number of substances	%
Paper and pulp	- ECHA, 2017*	4075	18%
	- SPR, 2015*		
	- EFSA, 2012		
	- Zellcheming, 2008		
	- Experimental literature, 1988-2016*		
	- DPR, 2015*		
	- NPR, 2015		
Printing	- ECHA, 2017*	16117	71%
	- SPR, 2015*		
	- FDHA, 2005		
	- BMEL, 2016		
	- EUPIA, 2013		
	- Danish EPA, 2011		
	- Experimental literature, 1988-2016*		
	- DPR, 2015*		
Other**	- ECHA, 2017*	2536	11%
	- SPR, 2015*		
	- Experimental literature, 1988-2016*		
	- DPR, 2015*		

*Source provides information on substances used in more than one industrial sector;

**Industrial sectors other than paper and pulp or printing.

Most of the substances derived from either EUPIA inventory list or Swiss Federal Department of Home Affairs (FDHA) ordinance “positive” list (Figure 14). The smallest numbers of substances were provided in the publication describing use of chemicals in paper and pulp production⁷⁴ or the Norwegian Product Register (NPR). Since the reviewed information sources had specific geographical references (e.g. Norway for NPR), it was possible to attribute each of the substances either to a specific country or to a region (Figure 15). By number of substances, most were within broader European geographical scope, since both

⁷³ Pivnenko et al. 2016b

⁷⁴ Zellcheming, 2008

EUPIA and ECHA inventory lists concerned the EU and not a specific country within the region. Country- specific information sources with the largest numbers of substances reported concerned Switzerland (FDHA ordinance (“positive” list)), Denmark (Danish Product Register (DPR), Danish printing industry inventory (Danish EPA) and selected experimental literature), Germany (ordinance of the Federal Ministry for Food and Agriculture of Germany (BMEL) on printing inks and selected experimental literature) and Sweden (Swedish Product Register, SPR). While Figure 15 represented the geographical relevance of the substances covered in the present work, it did not mean that distribution of substances in Figure 15 reflected numbers of substances actually used in the respective countries or regions. For example, Switzerland did not necessarily use more substances in paper and paperboard manufacturing when compared to the rest of countries mentioned in the Figure 15.

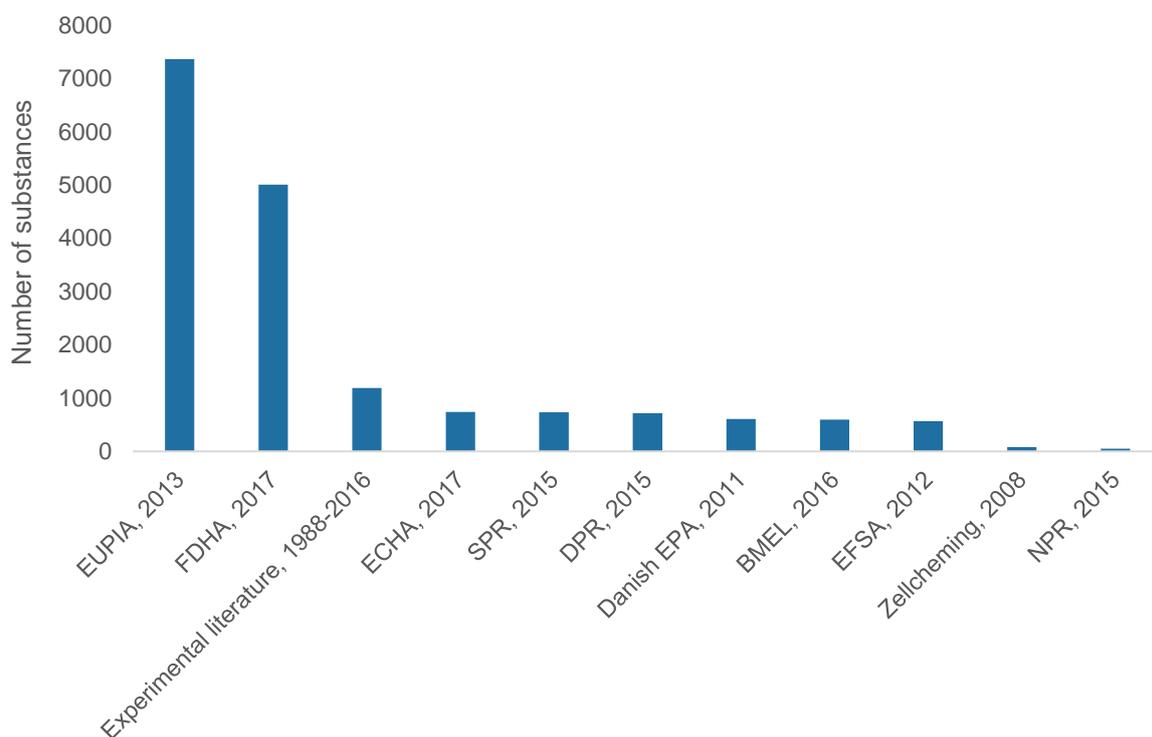


Figure 14. Distribution of number of substances by source of information reviewed in the present report (see detailed description in Appendix A1). The majority of substances derived from the European printing inks inventory (EUPIA, 2013) and Swiss legislation on printing inks (FDHA, 2017).

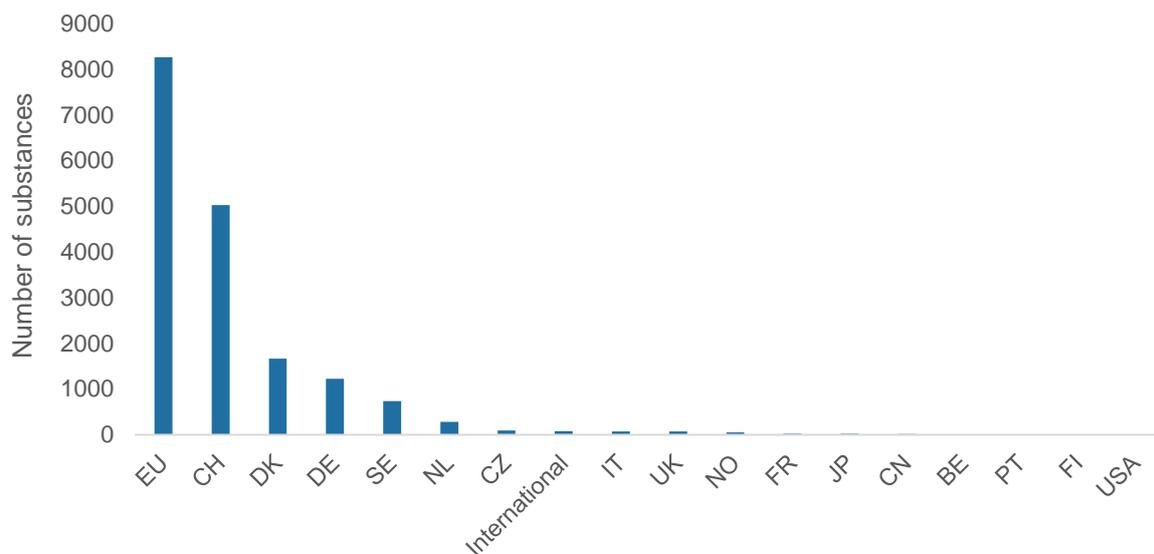


Figure 15. Distribution of number of substances by country or region, as reported in information sources reviewed in the present report. “EU” or “International” means the information source did not distinguish between different countries within a geographical region (e.g. European printing inks inventory concerns the EU in its scope).

Table 9. Distribution of number of substances by information type relevant to the study. Including duplicate values

Type of information	Information source	Number of substances	%
Inventory (Paper and pulp production)	- ECHA, 2017* - SPR, 2015* - EFSA, 2012 - Zellcheming, 2008 - NPR, 2015 - DPR, 2015*	1779	10%
Inventory (Printing)	- ECHA, 2017* - Danish EPA, 2011 - EUPIA, 2013	8055	46%
Inventory (Production and printing)	- ECHA, 2017*	202	1%
Positive list (Printing inks for food contact applications)	- FDHA, 2017 - BMEL, 2016	5604	32%
Targeted/Non-targeted chemical analyses	- Experimental literature, 1988-2016	1191	7%
Other**	- ECHA, 2017* - SPR, 2015* - DPR, 2015*	825	5%

*Source provides information on substances classified in more than one type of information;

**Type of information not covered by other entries (e.g. use of adhesives).

Information type “other” in Table 9 included substances not covered by the rest of the information types mentioned in the table. For example, some substances from the ECHA list could be attributed to paper and pulp production or printing, while other substances on the list could result from other paper product manufacturing activities (e.g. adhesive application). Similarly, some of the substances from Swedish and Danish product registers, could be used in paper production, printing or other processes (e.g. B15330: Fibre, leather, rubber and polymerised materials preservatives).

To be able to focus on the application and function of the most relevant substances among the identified ones, the number of substances had to be reduced. The prioritisation of substances was defined and discussed in the following section (Prioritisation of substances).

Prioritisation of substances

Due to the large number of substances identified as potentially relevant to the aim of the project, a prioritisation approach was applied. The prioritisation of substances was performed according to the methodology described in Appendix A1. Prioritisation results are graphically represented in Figure 16 and based on data presented in Table 9. The prioritisation approach was primarily based on the information source of identified substances, focusing on substances in use in Sweden as part of paper production or paper article manufacturing (see Section 3.1.1). Swedish product register received the highest level of priority (project relevance), as the majority of paper and paperboard consumed in Sweden was domestically produced (see Section 3.1.1 for details). Hence, the substances registered on the Swedish

product register had the highest probability of being used in domestic production and being present in paper and paperboard articles on the Swedish market.

In addition to domestic production, imports of paper and paperboard articles from other EU countries were substantial (see Sections 3.1.1 for details). Producers in Sweden and other members of EU and CEPI have to comply with common chemicals legislation and paper manufacturing standards (e.g. technical guidelines on good manufacturing practices). Hence, difference in substance use for paper manufacturing in Sweden and the EU was not expected to be substantial and substances relevant to the EU received a lower priority in the present work. However, paper imports from the EU (similarly to paper manufactured in Sweden) could potentially also contain non-regulated substances or NIAS. To address this issue, potential contaminants present in paper on the European market were also identified. Due to complexity of contaminant definition and routes of contamination in paper (see Section 2.6 for details), substances not registered on any of the product registers, reviewed or registered by ECHA to be used in paper production or paper article manufacturing, but identified in the experimental literature were identified as potential contaminants. Identification of contaminants was performed by cross checking respective substance CAS numbers. Since for some substances CAS numbers were not reported, additional information on function of substances without reported CAS numbers was also provided. All substances identified in the present work, as well as additional information about each of the substances (depending on the priority level) are reported in Appendix B1.

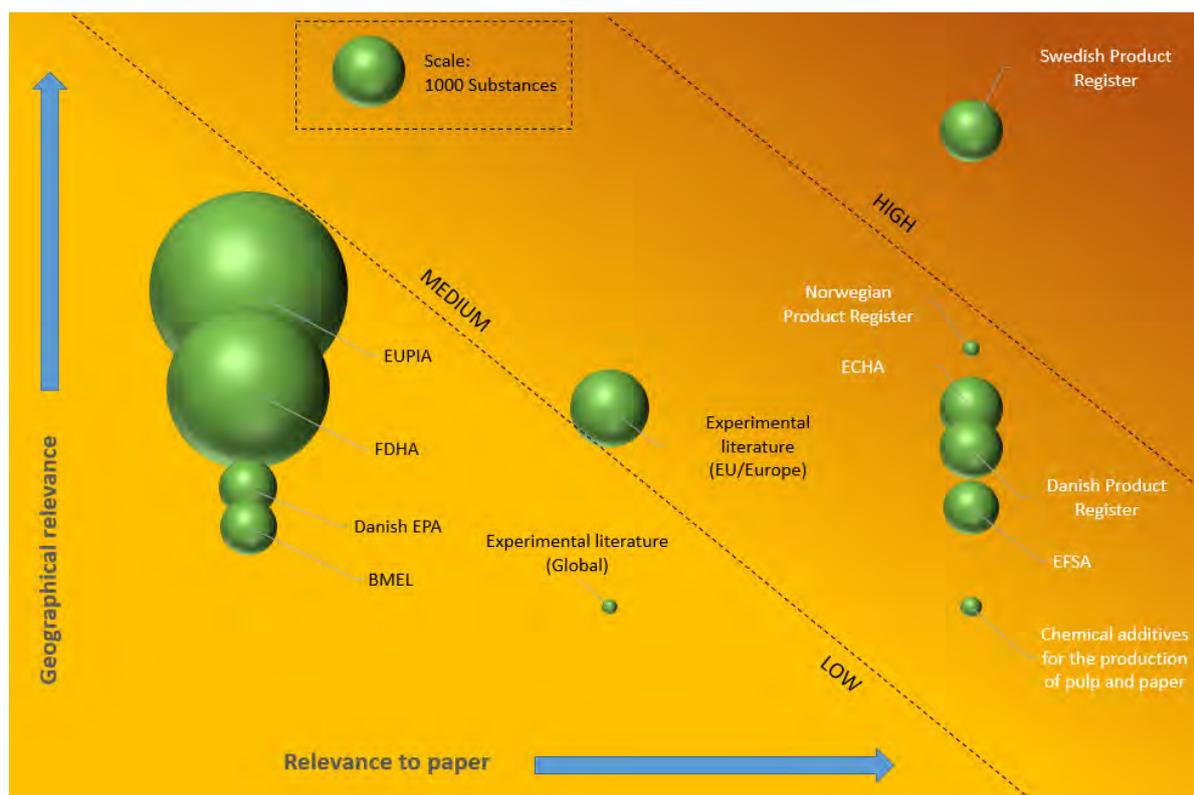


Figure 16. Graphical representation of data source prioritisation with relevance to the project (based on data from Table 9). Three distinct relevance levels outlined: Low, Medium and High. Sizes of bubbles represent number of substances derived from each data source⁷⁵

⁷⁵ Zellcheming, 2008

Table 10. Overview of information sources, number of substances derived from each source and project relevance factors and levels.

#	Information source	Number of substances	Factor of project relevance	Level of project relevance
1	Swedish Product Register	735	9	High
2	ECHA, 2017	741	6	Medium
3	Danish Product Register	714	6	Medium
4	Norwegian Product Register	50	6	Medium
5	EFSA, 2012	565	6	Medium
6	Experimental literature (EU/Europe)	1152	4	Medium
7	EUPIA, 2013	7367	2	Low
8	FDHA, 2017	5010	2	Low
9	Zellcheming, 2008	79	3	Low
10	Danish EPA, 2011	610	2	Low
11	BMEL, 2016	594	2	Low
12	Experimental literature (Global)	38	2	Low
	Total	17655	-	-

Each of the substances within high level of relevance (i.e. Swedish product register) was assigned potential function, based on the available information. Information on substance functions came from several sources, including information sources included in substance review and described in Appendix A1 i.e. EFSA, 2012, Zellcheming, 2008; Vápenka et al., 2016; EUPIA, 2013; Danish EPA, 2011; BMEL, 2016; personal communication with Swedish Chemicals Agency (KEMI), United States Environmental Protection Agency (US EPA), database on Chemical and Product categories⁷⁶, and expert opinion based on chemical structure of a substance and its potential use. The identified descriptors for substance use were classified in 24 function categories (e.g. inks, solvents, retention aids) and two additive types (process or functional additive).

Once duplicates were removed (based on CAS numbers), 567 unique substances were on the high relevance list. While all the substances come from the Swedish product register, some of the same substances were also reported in alternative information sources (Figure 17). This indicated that a substantial number of substances was used across different countries (Denmark, Norway, etc.) and sectors related to paper article manufacturing, i.e. pulp and paper production, and paper printing. In practice, this meant that information provided for substances of high relevance, also covered e.g. 90% and 40% of the Norwegian and Danish Product Registers, respectively (Figure 17). This was considered of relevance, as most of non-EU imports of paper and paperboard came from Norway. Imports from EU into Sweden were substantial, and share of substances used in production within EU was covered by the European legislation.

As previously mentioned, use of substances in paper manufacturing in Sweden and the EU was not expected to differ substantially. However, there were some differences and this was reflected by the fact that approximately 20% of substances registered by ECHA were also

⁷⁶ EPA 2017

covered by the Swedish product register (see Figure 17 for details). The fact that less than 100 substances on high priority list were covered by ECHA could partially be explained by differences in registration requirements. While chemicals manufactured or imported in quantities greater than 100 kg should be registered in the Swedish product register, current limit for European registration with ECHA was 100 tonnes per substance. Deadline for registration of substances produced or used in lower amounts (between 1 and 100 tonnes) was set to 31 of May 2018. The majority of substances registered by the Swedish product register (335) were produced or imported in amounts below 100 tonnes, while 144 substances were registered in rather small amounts (≤ 1 tonne). In addition, no quantitative data was available for more than 100 substances due to confidentiality requirements.

Based on the substance prioritisation employed in the present work, priority was given to identification of substances used in domestic manufacturing. Hence, not all the substances used in manufacturing abroad and potentially present in articles in Sweden were linked to specific applications in paper and paperboard manufacturing. As previously mentioned, in addition to substances derived from Swedish product register, substances reported without CAS number or potential contaminants were also focused upon. These substances were accounted for as part of the medium priority list and potential contaminants were marked (see Appendix B1 for details). For example, 4-cumylphenol (HPP, 599-64-4) is an analogue of bisphenol A (BPA) that can be used as developer in thermal paper. While HPP had not been registered in product registers and ECHA, it was identified in samples of shipping boxes and indicated as potential contamination.

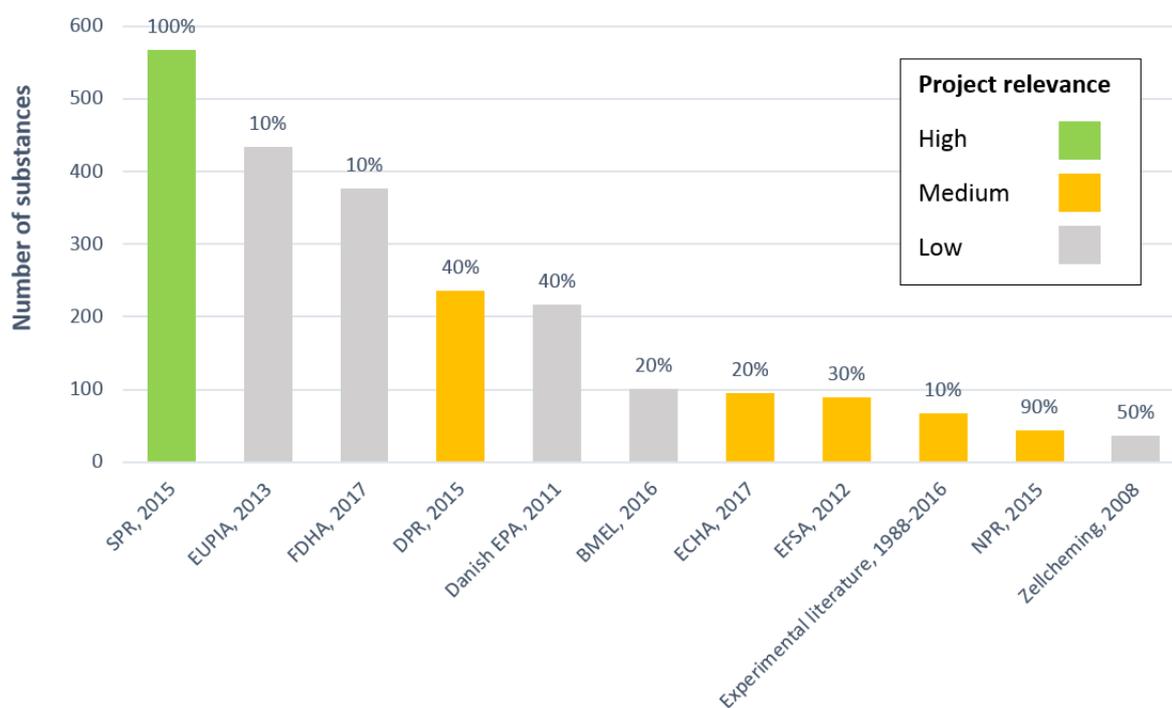


Figure 17. Number of unique substances (with CAS number) covered by the Swedish Product Register (SPR), and the overlaps with respective information sources. Percentage values represent share of the substances on the respective information source (duplicates removed), covered by the substances on the SPR.

Figure 18 illustrates function distribution of the focus (Swedish product register) substances of high relevance. The majority of substances (54%) could be associated with inks, pigments,

colorants and dyes. This was also evident from Figure 17, where most of the high relevance substances could be found on the European printing inks inventory list⁷⁷. While inks were used primarily in paper and paperboard printing (paper conversion), pigments, colorants and dyes could also be applied in the paper production phase (see Section 2.3). The remaining 46% of substances could be subdivided into 18 function categories, with “synthetic binders” and “solvents and lubricants” being the most common (9% and 8% of the substances, respectively). Solvents were primarily organic substances used in printing industry, as part of ink formulation. Approximately 3% of the substances were classified as “other”, which includes substances used as antioxidants, rheology modifiers, photo-initiators, etc. Function of approximately 2% of substances in pulp and paper production or printing was unknown. The list containing high priority substances referred to substances currently used in Sweden, among the substances potentially relevant for the European market (i.e. medium priority lists) around 380 substances were identified as potential contaminants (see Appendix B1 for details). These substances were identified in the experimental literature, but were not registered on either of the product registries or ECHA list for use in paper production and manufacturing. Examples of such substances were selected phthalates (e.g. didecyl and dipentyl phthalates) and selected toxic metals (e.g. Cd, Cu, Ni).

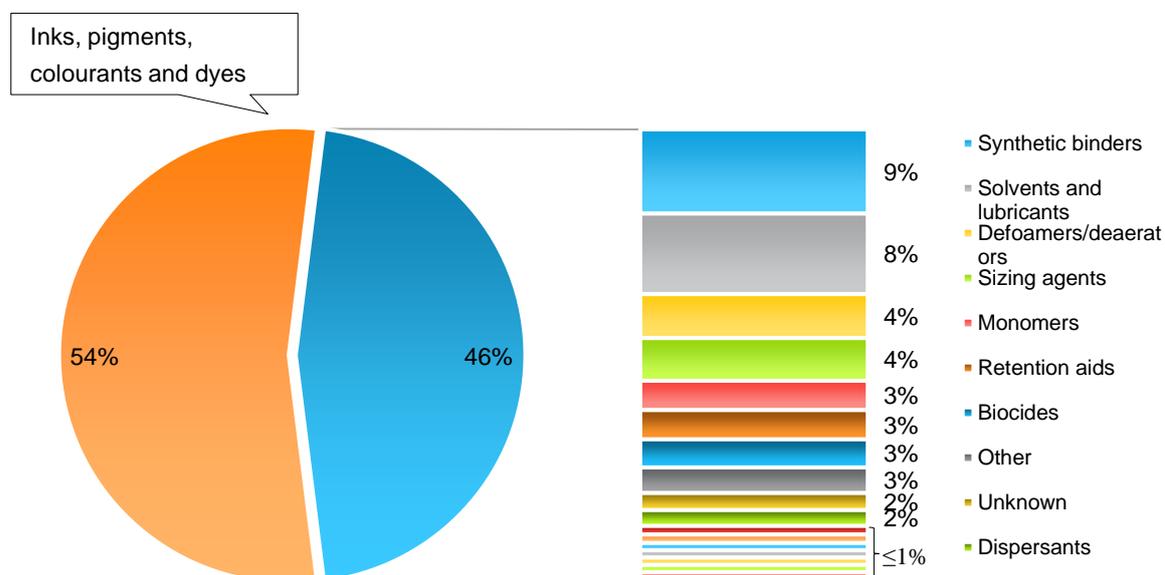


Figure 18. Distribution of substances of high relevance by function in paper and pulp production or printing. The majority of substances (54%) could be associated with inks, pigments, colorants and dyes.

Since identification of potential contaminants in paper from Europe was based on use of substances CAS numbers (to cross check with reviewed product registers and ECHA list), some of the substances without reported CAS numbers could be potential contaminants. To obtain additional information on nature of those substances, their potential function and type of additives they could be used in were also identified based on expert evaluation (see Appendix B1 for details). The majority of substances without reported CAS numbers could be used as surfactants, biocides, solvents, etc. Considerable number of substances were not attributed to a function, primarily because they were not identified (instrument response not matched to a library), were identified as a generic group (e.g. fatty acid esters, resin acids,

⁷⁷ EUPIA 2013

reaction masses), or can be potential impurity or reaction and degradation products (e.g. polychlorinated biphenyls, mineral oil saturated and aromatic hydrocarbons)

Finally, there could be a difference in production standards and chemical legislation for materials and articles manufactured in countries outside Europe. For example, experimental literature had documented presence of toxins, including dioxins and furans, in paper materials manufactured in China⁷⁸. However, up-to-date information on presence of dioxins in paper articles was unavailable and measures for reduction of dioxin formation in paper production had been reported⁷⁹. The difference between regions could be reflected not only in the types of substances used, but also the amounts applied. For example, it was shown that thermal paper from America contained higher amount of selected developers (bisphenol A and S) when compared to data from Europe or Asia⁸⁰. Nevertheless, presence of substances (intentionally or unintentionally) added to materials imported from outside Europe was of limited relevance to the present project since such paper and paperboard imports into Sweden were negligible. This could be relevant for non-apparent imports of paper and paperboard as part of packaging and documentation for paper articles, however, amounts and composition of these materials were highly uncertain.

It should be noted that quantitative data for amounts of substances used or present in paper and paperboard materials was rather sparse. To provide quantitative estimates of the amounts of substances potentially present in paper material, quantitative data from experimental literature was supplemented by quantity assumptions. For example, only residues of process chemicals would likely remain in the final article. Hence, in the Appendix B1 it is assumed that concentration in final article is less than 0,1% (see Appendix B1 for more details).

List of prioritised substances

The present report is accompanied by an Excel document containing lists of substances separated into different relevance levels (see Appendix B1). The document is separated into six datasheets (the names of the sheets are written in italic below) providing the following information:

- *Intro*. Contains description of information provided in the remaining datasheets, data sources for substance identification (see Appendix A1 for details) and their brief descriptions. In addition, it contains acronym explanation for geographic references used throughout the document.
- *Low*. Contains substances of low relevance to the project in accordance to the methodology described in Appendix A1. It contains following data columns: Substance name and CAS number, geographic reference, type of data source, data source and reference to the data source.
- *Medium (CAS)*. Contains substances of medium relevance to the project in accordance to the methodology described in Appendix A1. It contains following data columns: Substance name, CAS number, EC/List number (if provided), geographic reference, and identification of a substance as potential contaminant, type of data source, data source and reference to the data source.
- *Medium (no-CAS)*. Since identification of potential contaminants was based on CAS numbers, substances where CAS numbers were not reported in the original

⁷⁸ Zheng, M et al. 2001

⁷⁹ The World Bank 2012

⁸⁰ Pivnenko et al. 2018

information source are reported separately. Additive application and potential function were also provided. Contains substances of medium relevance to the project in accordance to the methodology described in Appendix A1. It contains following data columns: Substance name, EC/List number (if provided), geographic reference, type of additive application (functional, process or coating), potential function (e.g. pigment, surfactant), type of data source, data source and reference to the data source.

- *High*. Contains substances of high relevance to the project in accordance to the methodology described in Appendix A1. It contains following data columns: Substance name, CAS number, EC/List number (if provided), geographic reference, type of additive application (functional or process), identification of all potential functions or uses (e.g. inks, solvents, biocides), product category substance is potentially used in, product examples, uncertainty in presence of the substance in specific product category(-ies), tentative quantitative data in terms of 1) Total use in Sweden for paper manufacturing (as reported in SPR); 2) Material content; 3) Min concentrations reported; and 4) Max concentrations reported. In addition, it is reported in which of the reviewed data sources substance was mentioned. Similarly, to other relevance levels, type of data source, data source and reference to the data source are also reported.
- *Functional classification*. In addition to expert evaluation, classification of substances of high relevance into different function categories (e.g. inks, solvents) was based on a variety of descriptors obtained from the available literature. Present datasheets contain details on how the collected descriptors were related to specific function categories. Attribution of functions to medium priority substances without CAS number was based only on expert evaluation, see Appendix A1.

Guideline - List of prioritised substances

Shortly, Appendix B1, sheet “High” can be used in following way;

- Column A-D consists of basic information regarding the specific substance
- Column F states if a substance is a process chemical, functional chemical or both⁸¹.
- Columns G-AD specify the function(s) of the substances e.g. biocide, anti-foaming agent or sizing agent.
- Column AG and AH lists the paper grades (AG) and paper articles (AH) where it could be possible to detect the substance or where the substances could have been used in the production process

3.3.2 Articles made of graphic paper

In this project, it was found that articles made of graphic paper (e.g. newspaper, magazines and copy paper) could consist of chemical, mechanical and recycled pulps or combinations of these. Functional chemicals tended to be similar for various applications (i.e. articles), but the quantity could vary. For example, the amount of fillers and pigments varied to achieve the desired rigour and colours; therefore, newspaper, magazines and copy paper differed in rigour and colour. Common functional chemicals, for graphic papers, are fillers, pigment and dyestuff and dry strength agents. The use of chemicals is mainly dependent on the final property requirements for different applications. A few examples of paper articles and the use of different chemicals are summarised below, see also Appendix B1 for details.

⁸¹ Coating chemicals are, in this instance, considered functional chemicals

Newspaper

Pulp: Mechanical pulp, chemical pulp and recycled pulp.

Requirement profile: Good printing properties, so it has to have a smooth surface and ability to absorb oil. In addition, other important properties are brightness and tensile- and tear strength and its colour (e.g. pink sport pages)⁸².

Additives: To obtain tensile- and dry strength, dry strength agents such as ionic macromolecules, acryl-amide-acrylic acid polymers, modified starch or polyvinyl alcohol can be used⁸³. As reported in Appendix B1, examples of dry strength agents are oxidized starch (CAS 65996-62-5) and hydrolysed starch (CAS 8029-43-4) used in Sweden (high priority) and cyclohexanone resins (non-CAS) that can also be used as dry strength agent in Europe (medium priority list).

Colorants used are often organic basic (cationic) dyes⁸⁴.

Fillers are commonly not used. However, fillers by up to 15% can be added to increase the density of the paper when a high proportion of recycle pulp is used.

Printing inks are applied for the end-purpose⁸¹. Some substances reported in Appendix B1 are natural oils (CAS 8001-22-7) and pigments (CAS 5281-04-9).

Finishing: To obtain good printing properties newsprint can be subjected to calendaring for a smoother surface.

Low-end magazines

Pulp: Consist of 50 – 100 % mechanical pulp. To increase the strength properties chemical pulp can be added⁸⁵ The pulp can be bleached or unbleached.

Requirement profile: Good printing properties, so must have a smooth surface. In addition, other important properties are gloss, density, wet- and dry surface strength, heat resistance during drying, and low ink absorption⁸⁴.

Additives: To obtain wet surface strength, wet strength agents can be used. Wet strength agents are e.g. water soluble cationic polymers with multiple reactive functional groups such as urea- and melamine formaldehyde resins, polyamines. As reported in Appendix B1, examples of wet strength agents were siloxanes (CAS 68083-19-2) and hydrocarbon waxes (CAS 64742-60-5) used in Sweden (high priority) and paraffins and polyamides (non-CAS) that can also be used as wet strength agents in Europe (medium priority list).

Dry strength is gained by using dry strength agents. Dry strength agents are e.g. ionic macromolecules such as acryl-amide-acrylic acid polymers, modified starch or polyvinyl alcohol.

Low ink absorption can be gained by sizing using for example rosin (CAS 8050-09-7) listed in Appendix B1 (high priority)⁸⁶. Low-end magazines are often uncoated, but can be lightweight coated.

⁸² Paulapuro 2000

⁸³ Hagiopol & Johnston 2012

⁸⁴ Eklund & Lindström 1991

⁸⁵ Paulapuro 2000

⁸⁶ Hagiopol & Johnston 2012

Printing inks are applied for the end-purpose. There is a vast amount of substances that can be used in an ink formulation, for details see Appendix B1. One example used in Sweden (high priority) are the azo dyes (CAS 5102-83-0 and CAS 5567-15-7).

Finishing: Uncoated papers are often subjected to super-calendaring⁸⁵.

High-end magazines

Pulp: Consist of 50 -100% mechanical pulp. To increase the strength properties chemical pulp can be added⁸⁴. In general, the proportion of chemical pulp is higher in high-end magazines than in low-end magazines. Pulp for high-end magazines can be either bleached or unbleached.

Requirement profile: Important properties are brightness, opacity, and sheet stiffness to avoid cracking while folding.

Additives: High-end magazines are medium- to heavy weight coated and have two to three layers of coating⁸⁴. Fillers and optical brighteners are used in the coating mixture to give the paper brightness and opacity. Some fillers used in Sweden (high priority) reported in Appendix B1 are talc (CAS 14807-96-6) and calcium carbonate (CAS 471-34-1). Optical brighteners reported in Appendix B1 are stilbenes (CAS 4193-55-9), these can also be of non-CAS (medium priority list) reported to be used in Europe. Both organic and inorganic pigments can be used in the coating mixture⁸⁷. The coating gives the paper gloss and smoothness.

Printing inks are applied for the end-purpose.

Finishing: Finishing such as calendaring is commonly not used to the coating.

Copy papers:

Pulp: Consist of chemical pulp (either hardwood or softwood bleached pulp) or recycled pulp or a mixture of both⁸⁸.

Requirement profile: Important properties are surface strength, brightness, good archival properties, low linting and dust formation during printing and colouring (for coloured papers)⁸⁷.

Additives: Sizing agents, both natural (e.g. modified starch) or synthetic (e.g. dispersion of pentaerythritol, glycerol ester of rosin), can be used to acquire surface strength and prevention of linting and dust formation⁸⁹. As reported in Appendix B1, examples of sizing agents were modified starches (CAS 65996-62-5 and CAS 68187-08-6) used in Sweden (high priority) and resins and polymers (non-CAS) that can also be used as sizing agents in Europe (medium priority list).

Filler content of copy paper is often 10-25%. The filler is often clay or calcium carbonate. Organic and inorganic pigments can be used to add colour to the paper⁹⁰.

Printing inks (e.g. jet inks) are often applied during use in the printing process.

Finishing: Copy papers are often calendered.

⁸⁷ Eklund & Lindström 1991

⁸⁸ Paulapuro 2000

⁸⁹ Hagiopol & Johnston 2012

⁹⁰ Eklund & Lindström 1991

Table 11. Graphic paper and Sanitary and household paper and type of pulp, surface treatment and functional chemicals that are used in the paper production^{87,88,89,91,92} See Appendix B1 for more details.

Paper and paperboard category		Pulp	Surface treatments	Functional/Process chemicals
Graphic paper	Newsprint	Thermomechanical pulp Sulphate pulp	-	Fillers – e.g. clay (not commonly used) Pigments and dyestuff – e.g. organic basic (cationic) dyes Optical brightener -e.g. 4,4 – diaminostilbene-2,2-disulphonic acid
	Mechanical paper	Thermomechanical pulp, Chemical pulp	-	Fillers -e.g. clay Pigments and dyestuff -e.g. organic and inorganic pigments Bleaching agents – e.g. sodium hydroxide, hydrogen peroxide
	Woodfree paper	Sulphite pulp	Surface sizing	Fillers – e.g. clay or calcium carbonate Pigments and dyestuff – e.g. organic and inorganic pigments
Sanitary and household paper	Toilet paper	Chemi-thermomechanical pulp Sulphate pulp	-	Softener – e.g. cationic terylamide, imidazoline molecules with incorporated polyether, ethoxylated fatty alcohols Optical brightener -e.g. 4,4 – diaminostilbene-2,2-disulphonic acid Bleaching agents e.g. hydrogen peroxide
	Tissues and napkins	Sulphate pulp	-	Softener – e.g. cationic terylamide, imidazoline molecules with incorporated polyether, ethoxylated fatty alcohols Optical brightener -e.g. 4,4 – diaminostilbene-2,2-disulphonic acid Bleaching agents e.g. hydrogen peroxide Pigments and dyestuff – e.g. acid dyes, direct dyes Wet strength agents – e.g. Urea and formaldehyde based resins
	Household and hygienic paper	Chemi-thermomechanical pulp Sulphate pulp	-	Softener – e.g. cationic terylamide, imidazoline molecules with incorporated polyether, ethoxylated fatty alcohols Optical brightener -e.g. 4,4 – diaminostilbene-2,2-disulphonic acid Bleaching agents e.g. hydrogen peroxide Pigments and dyestuff – e.g. acid dyes, direct dyes Wet strength agents – e.g. Urea and formaldehyde based resins

3.3.3 Articles made of sanitary and household paper

For sanitary and household paper (e.g. toilet paper) the most common pulps are chemical and mechanical pulp. Functional chemicals can vary between articles in this paper grade, for example wet strength agents are used in the production of household paper but not in toilet paper i.e. toilet paper needs to dissolve in the sewage while household paper is thrown in the bin.

⁹¹ Survey, Swedish paper industry, 2017

⁹² OECD 2014

Common functional chemicals are fillers, pigment and dyestuff. It is not common use surface treatment for this grade since toilet paper and household paper shall be able to soak up water and surface treatment would lower that ability.

Toilet paper

Pulp: Consist of virgin fibre sulphate pulp (chemical pulp) or recycled pulp^{93,94}.

Requirement profile: Important properties are tensile strength, whiteness and brightness, high absorption, flexibility, surface softness, low bulk density. Colour can in some cases be important depending on the final article⁹³.

Additives: The toilet paper has to have high absorption capacity, to achieve this non-ionic surfactant can be used e.g. alkyl glycoside ethers and alkyl polyethoxylated esters.

To achieve surface softness and low bulk density, adhesives e.g. poly 2-ethyl-2-oxazoline, polyvinyl alcohol, polyamine tetraethylammonium salt and softening additives e.g. cationic terylamide, imidazoline molecules with incorporated polyether, ethoxylated fatty alcohols and linear fatty acids can be used⁹⁵.

Bleaching improves brightness and absorption properties and optical brightening agents may be added to improve the effect⁹³.

Finishing: Toilet paper is often embossed to give a more bulk impression⁹³.

3.3.4 Articles of packaging paper

Packaging paper is made from chemical, mechanical and/or recycled pulps. Common functional chemicals that are used in the production are fillers, pigments and dyestuff, sizing agents and wet strength agents. Packaging paper can both be treated and not-treated by surface treatment. Wrappings (e.g. grocery paper bags) tend to not be coated. Cases (e.g. boxes to display an item) and packaging paper tend to be coated.

Baking papers (grease proof papers)

Pulp: Sulphate pulp. Sulphate pulp is used since it gives the baking paper heat resistant-properties.

Requirement profile: Important properties are grease proof, heat resistance, opacity, low porosity and high density⁹³. Colour can sometimes be important for the final appearance⁹⁶.

Additives: Greaseproof properties are gained by using a silicone or wax coating. Titanium dioxide is used as a filler to increase opacity.

Chemical pulp is used as it gives heat-resistance properties to the paper⁹⁵.

Colorants can be either organic dyes or inorganic pigments⁹⁷.

Finishing: Baking paper is often supercalender.

Containers for milk and juice

⁹³ Survey, Swedish paper industry, 2017

⁹⁴ Paulapuro 2000

⁹⁵ Hagiopol & Johnston 2012

⁹⁶ Personal communication, Swedish paper industry 2017

⁹⁷ Eklund & Lindström 1991

Pulp: The top and bottom layer is made from chemical pulp, either bleached or unbleached. The bulky middle layer is made from mechanical pulp (CMTP) 50%⁹³.

Requirement profile: Important properties are cleanness and purity, bending stiffness, compression- and tensile strength, dry strength, surface smoothness in respect to printability, adequate barrier properties, purity and cleanness⁹⁸.

Additives: To achieve tensile- and dry strength properties, dry strength agents e.g. ionic macromolecules, acryl-amide-acrylic acid polymers, modified starch or polyvinylalcohol can be used.

To achieve hydrophobic properties, sizing chemicals such as rosin can be used⁹⁹.

For containers aimed to be used for lactic acids, AKD substances, such as 2-oxetanone, 3-C12- 16-alkyl-4-C13-17-alkylidene derivates (CAS 84989-41-3) are used for sizing, reported in Appendix B1 (high priority).

To coat the paper polymers e.g. polyethylene can be used.

Biocides or heat-treatment can be used to achieve antiseptic packaging⁹⁷.

Printing inks can be applied depending on the application.

Finishing: Calendering is common.

Corrugated box

Pulp: Liner (outer layer) is made from chemical pulp or recycled fibres, bleached or unbleached. Fluting medium (bulky layer) is made from chemi-thermo mechanical pulp and recycled fibres.

Requirement profile: Important properties are crush and bursting strength, compression strength, stiffness, and glue-ability. Depending on final article good printing properties can be important⁹⁷.

Additives: Fillers to increase the density. To achieve an even shade of brown, brown boxes are coloured with water-based brown colorants. Pigment coating e.g. calcium carbonate is used for white boxed.

The liner is often sized for moisture resistance using substances such as oleic acid (CAS 112-80-1), rosin, tall-oil rosin, fumarated (CAS 85631-69-2) that been reported in Appendix B1 (high priority). Starch may be used for improving strength properties¹⁰⁰.

Boxes can be coated or uncoated. Printing inks can be applied depending on the final article.

Finishing: Corrugated boxes are often sized, coated or both.

⁹⁸ Paulapuro 2000

⁹⁹ Hagiopol & Johnston 2012

¹⁰⁰ Personal communication, Swedish paper industry 2017

Table 12. Packaging papers and type of pulp, surface treatment and functional chemicals that are used in the manufacturing process^{101,102}

Paper and paperboard category		Pulp	Surface treatments	Functional chemicals and example substances
Packaging papers	Case materials	Sulphate pulp Recycled fibre pulp Chemical pulp	Coatings	Fillers – e.g. kaolin and calcium carbonate Pigments and dyestuff – e.g. calcium carbonate Bleaching agents -e.g. hydrogen peroxide
	Wrappings	Sulphate pulp	No surface treatments	Sizing agents (water repellent) – e.g. starch, waxes Wet strength agents e.g. urea- and formaldehyde based resins Binders - e.g. carboxylated styrene-butadiene
	Papers for groceries e.g. baking paper, grease proof paper, charcuterie paper	Sulphate pulp Sulphite pulp	Surface sizing Coatings	Filler – e.g. titanium dioxide Grease proof agents – e.g. silicone or wax coating Pigments and dyestuff – e.g. titanium dioxide, zinc oxide, organic dyes or inorganic pigments
	Various packaging article	CTMP Sulphate pulp	Coatings Pigment coatings	Fillers – e.g. kaolin and calcium carbonate Pigments and dyestuff – e.g. titanium dioxide Binder – e.g. carboxylated styrene-butadiene Sizing agents (water repellent) – e.g. starch, waxes Strength agents – e.g. urea- and formaldehyde based resins Bleaching agents – e.g. hydrogen peroxide Biocides – e.g. Organic bromine, hydrogen peroxide

In the examples of common paper articles, the properties of the articles were used to predict their functional chemicals. The predicted functions of chemicals were partly based on practical knowledge from material development of paper. For more details, see Appendix A1.

¹⁰¹ Survey, Swedish paper industry, 2017

¹⁰² Personal communication, Swedish paper industry, 2017

4 Conclusion

The aim of this project was to identify chemicals in paper and paperboard consumer articles on the Swedish market. Most articles on the Swedish market were domestically produced and, hence, the focus in this report was on Swedish producers and the chemicals they used in their manufacturing.

This report demonstrated the linkage between paper articles and the substances used to produce these articles. It was noteworthy that paper articles contained mostly fibres and the choice of fibre pulp could have major importance on the properties of the articles. One example was baking paper that had to be made of sulphate pulp, since sulphate pulp made the paper heat resistant. In addition to the choice of pulp, the added chemicals could have an impact on the functionality of the final article. For example, the main difference between household paper and toilet paper was that household paper contained wet strength agents. Toilet paper should not contain wet strength agents since it should be flushed down the toilet and dissolved in sewers. Summarised, consumer paper articles could have different chemical composition depending on the pulp and chemicals used to make the final paper article.

To achieve the linkage between the paper grade/article and substances used in the manufacturing of the paper grade/article, several steps were conducted. Firstly, consumption pattern of paper articles were identified. This included identification of the origin of the paper articles placed on the Swedish market as well as consumption levels. To identify relevant paper grades a prioritisation model was developed based on exposure estimations and quantities of paper grades on the Swedish market. To provide an overview of specific substances used during paper production and article manufacturing a large number of potentially relevant substances was identified. To be able to identify the functionality of most relevant substances and to provide a link to specific paper grades, it was necessary to prioritise among the substances. The prioritisation of substances was made on the basis of origin of the paper articles on the Swedish market and the substances relevance to paper article manufacturing (see Appendix B1 for the substances and their prioritisation). The linkage between substances, their functionality and presence in paper grades and articles (see Appendix B1) was achieved by information from various data sources, including scientific literature, and practical knowledge within the paper industry.

Substances used in the paper production had often more than one potential function, e.g. starch could function both as a binder and a sizing agent, and often several different chemicals could achieve the same function. It could be an advantage to refer to the function of a chemical group instead to a specific substance. This approach could be more suitable since the industry could use similar substances to achieve same function.

Substances used in Sweden were prioritised (“high” relevance list, Appendix B1); however, additional substances could be detected in paper articles on the Swedish market. There could be a difference between geographical regions in terms of substances used. Noteworthy, paper articles produced elsewhere than Sweden tended to be produced within the EU or EEA that also complied with the three main chemical regulations EC no 1907/2006 (REACH), EU no 528/2012 and EC no 1935/2004 (see Section “Definition and abbreviations” for full names of regulations).

The impact, on paper articles on the Swedish market, of newly regulated substances or substances used in other geographical places through recycling is considered as minor. The minor impact was due to the limited use of recycled pulp as well as limitations in fibres recycling. In addition, recycled pulp went through a cleaning process before being used in a

new application. However, contaminants and impurities could be incorporated into the paper article through various pathways and, thus, potential contaminants were identified (see Appendix B1, Medium priority).

Complete risk assessment of the identified substances and paper products was beyond the scope of the project; however, in case of future risk assessments it will be important to identify if substances are embedded or non-embedded in the article. In general, non-embedded chemicals are of greater concern than embedded due to the higher risk of release. Non-embedded chemicals that may be of great concern are coating chemicals that may have residual monomers in the binders, solvents and co-solvents and biocides used in the water-borne coatings. Dyes, stabilisers and photo-initiators present in coating and printing inks may also need to be considered for the risk assessment. Since process chemicals are expected to be present in relatively low concentrations, health risks arising from such chemicals may be of lower importance.

In conclusion, this report described the relationship between paper articles, its pulp and necessary chemicals to achieve the desired characteristics. The linkage is presented both in this report as well as in the separate Appendix B1.

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Appendices

A1. Methodology

The project was performed in various steps (Figure 19). During the first step, data including statistics were collected and exposure was estimated. This data was used to do further prioritisations among the data for the final step. In the final step, the identification of substances in articles of paper and paperboard was performed.

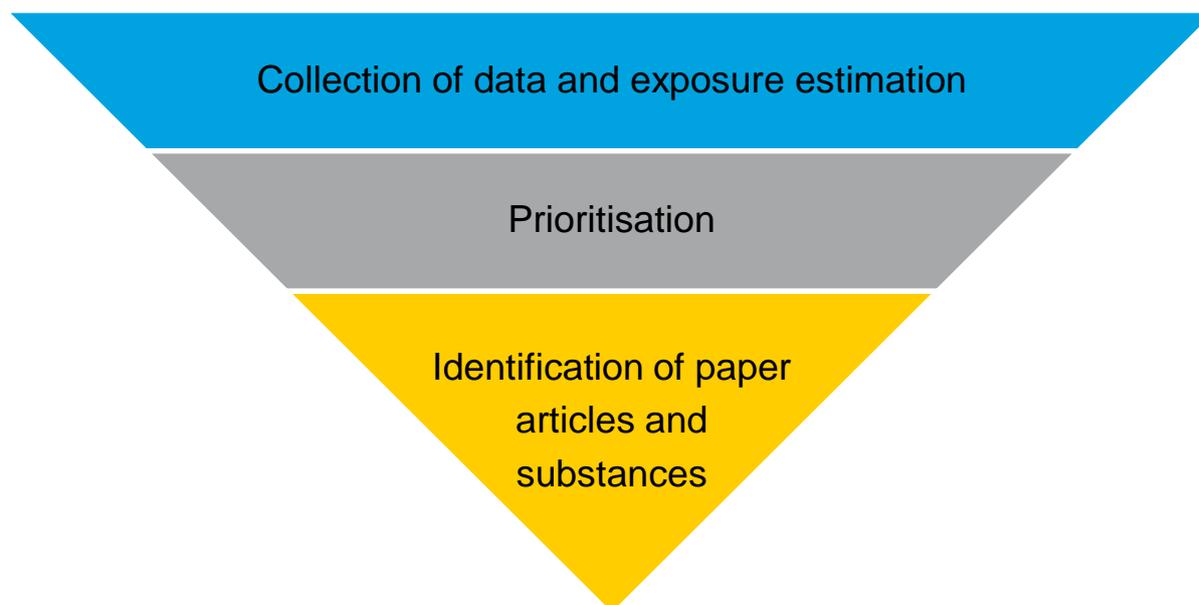


Figure 19. Overview of project. The project was divided into three steps. Step 1. Collection of data and exposure estimation, Step 2. Prioritisation and Step 3. Identification of articles and substances.

A1.1. Collection of data and exposure estimation

Statistics regarding quantities of paper articles and paper grades

During this step data regarding quantities of the paper articles and paper grades on the Swedish, EU and global market was collected and analysed. The aim of this step was to identify the region that had most impact on the paper articles on the Swedish market.

The data was collected from the Statistics Sweden, Swedish Forest Industries Federation and CEPI and consists of quantity of production, import and export on the Swedish market, and import data from the EU that included import to the EU from a third country.

Data from the Swedish Forest Industries Federation and Statistics Sweden was used to identify quantities of paper and paperboard on the Swedish market^{103,104}.

Data from Statistics Sweden was used to identify quantities of paper and paperboard imported to Sweden from EU resp. third countries¹⁰¹.

Data from CEPI was used identify consumption of paper materials in EU

¹⁰³ Statistics Sweden 2016

¹⁰⁴ Swedish Forest Industries Federation 2016

Collection of information regarding production processes, pulp and chemicals

Market research was conducted by sending a survey to actors in pulp and paper industry in Sweden. Identification of relevant companies and the distribution of surveys was performed through contacts with Swedish Forest Industries Federation. The working process is described in Figure 20.

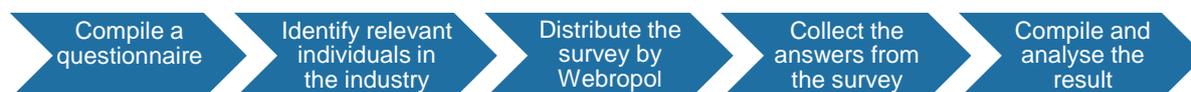


Figure 20. Flowchart of the work process for a market research in the Swedish paper industry

The survey was designed to obtain information about paper and paperboard. The questions regarding chemicals were based on the report Pulp and Paper Industry- Definitions and Concepts by CEPI, 2014 as well as consultations with the Swedish Forest Industries Federation.

The questionnaire was designed to provide information on what paper and paperboard materials that were manufactured at the site in question. The questionnaire covered pulp composition (mechanical pulp, chemical pulp and/or recycled pulp) used in different paper articles, as well as chemical groups used during the production.

More about the survey

Out of the 23 invited companies, 13 companies answered the survey. The respondents represented mills in Sweden. The represented mills in the survey had a total capacity of 6 192 000 ton paper/year out of the total capacity in Sweden of 13 278 000 ton paper/year¹⁰⁵. This represented a market share of 46,6%.

Statistics regarding usage of recycled pulp

Available statistics on use of virgin pulp and utilisation of recycled paper in the European paper production were reviewed. Most of the statistical data was derived from annual statistics reports prepared and distributed by CEPI. Reports for years 2016, 2014, 2012 and 2009 were used in the present work^{106,107,108,109} and supplemented by personal communication with CEPI.

Efficiency of utilisation of secondary raw materials in paper production was based on ranges of solid residues and sludge production for each of the seven paper grades i) cartonboard, ii) case materials, iii) household and sanitary, iv) newsprint, v) other graphic paper, vi) other paper and vii) wrapping and packaging) and presented in Pivnenko *et al.* (2016a).

Exposure scenarios

Exposure scenarios were developed to be used in Section A1. Prioritisation (see below). The exposure scenarios were based on estimations of everyday use (Table 6 and Table 7).

¹⁰⁵ Personal communication, Swedish Forest Industries Federation 2017

¹⁰⁶ CEPI 2009

¹⁰⁷ CEPI 2013

¹⁰⁸ CEPIb 2014

¹⁰⁹ Pivnenko and Astrup 2016

Table 13. Factors in the exposure scenarios. Listed factors were considered when developing the exposure scenarios.

Exposure pathways	Daily exposure
Direct contact via skin	Frequency of exposures
Direct contact with mucous membranes	Duration of exposures
Direct oral exposure through mouthing	-
Indirect oral exposure via food and drinks	-

It was estimated that direct oral exposure via mouthing of paper and board articles could give rise to the highest uptake of chemical substances followed by indirect oral exposure from food and drinks, direct contact with mucosal membranes and direct skin contact. Direct oral exposure was therefore considered as the most critical exposure pathway and direct skin contact the least critical exposure pathway. Indirect oral exposure from food and drinks and direct contact with mucosal membranes were considered as equally important.

Assessment of frequency and duration of exposure was not considered to be relevant for indirect oral exposure via food and drinks. Such exposures were more closely related to the amount of consumed food and drinks and the migration of substances from the material to the foodstuff. Paper and paperboard materials that were meant to be used in close contact with food and drinks were instead given extra priority compared to other materials.

The expected exposure pattern to paper and paperboard articles differed between i) younger children (<3 years old) and ii) older children (> 3 years old), adolescents and adults. Therefore, different exposure scenarios were developed for different age groups.

Younger children (<3 years old)

Young children explore their surroundings by putting objects in their mouth and are therefore extra vulnerable for direct oral exposure to consumer articles such as paper and board. The frequency of mouthing of objects reaches its peak between one to two years of age and rapidly decreases after three years of age^{110,111}. Also, children up to three years of age typically use diapers and are expected to have a high exposure to child sanitary articles such as baby wipes. Specific exposure scenarios were therefore developed for children up to three years old. The estimations of small children's exposure via mouthing of paper and board articles were based on the values of frequency and duration of object-to-mouth behaviour that had been developed by USEPA and recommended by the Nordic exposure group^{109,110}.

On average, children up to three years old mouth different types of objects eleven minutes per hour and they are awake twelve hours a day. This means that they have a non-dietary object in their mouth 130 minutes a day. To develop object-to-mouth exposure scenarios that were specific to paper and paperboard articles, it was estimated that one fifth of all non-dietary objects that children put into their mouth was made of paper or paperboard. This resulted in the estimation that young children mouth a paper or board article 26 minutes a day. It was estimated that the time small children were in direct skin contact with paper and paperboard articles was equal to the time they were mouthing these types of articles.

For exposure to household and sanitary papers via mucous membranes it was estimated that parents change diapers and wipe their children eight times per day and wipe the skin about one minute each time. For results, see Table 7.

¹¹⁰ TemaNord, 2012

¹¹¹ U.S.EPA 2008

Adults and older children (>3 years old)

When developing exposure scenarios, it was assumed that older children, adolescents and adults had a similar exposure pattern for paper and board consumer articles. The daily exposures to the different paper and paperboard material were based on estimations of frequency and duration for the expected and intended use of such articles. For results, see Table 6.

Identification of relevant substances

A variety of publicly available information sources was reviewed, identifying substances either used, present or potentially present in paper and paperboard materials and articles. Depending on the scope of each of the information sources reviewed, they could be separated in the following groups according to the type of information provided:

- Targeted/Non-targeted chemical analyses
- Inventory (Paper and pulp production)
- Inventory (Printing)
- Inventory (Production and printing)
- Positive list (Printing inks for food contact applications)
- Other

Data sources

Following sources of information were used in identification of substances potentially associated with paper material, paper and board articles.

1. *Experimental literature that provided targeted and non-targeted analyses of chemical substances in samples of paper and board* (Experimental literature, 1988-2016). Most of the literature was in form of peer-reviewed articles in international journals or scientific reports. In total, 31 publications were identified, covering the period between 1988 and 2016. While reviewed publications were not intended to cover specific geographic regions or temporal scopes, most of the publications had the EU or one of the European countries in scope. References to the complete list of reviewed publications from experimental literature is provided in Appendix B1.
2. *Substances registered by the European Chemicals Agency (ECHA, 2017) under REACH legislation (EC, 2006)*. Total number of substances registered: 18,494 (accessed September 2017). All the substances related to the article category 8 (AC8: "Paper"), were retrieved. Resulting in a list of 764 substances, Selected product categories were also searched to be used as proxy for each substance's function in paper applications. This information could be used to a limited extent as a single substance may be reported with a variety of functions, not all related to paper and paperboard manufacturing. By cross checking with the sector of use codes SU6b ("Manufacture of pulp, paper and paper products") and SU7 ("Printing and reproduction of recorded media") substances within article category 8 were assigned to pulp and paper production industry ("Inventory (paper and pulp production)"), printing industry ("Inventory (Printing)") or other industries, not identified by the two previous codes ("Other").
3. *Swedish Product Register (SPR, 2015)*. All substances under the industry NACE code C17: "Manufacture of paper and paper products" and UCN codes related to paper (see Appendix B1 for details) were retrieved. Obtained substance lists included CAS number for each of the substances, number of preparations a substance was used in and the total mass (tonnes) of the substance used in the selected industrial sector. Due

to confidentiality, only limited quantitative information was available for substances retrieved using UCN codes. Information was retrieved through personal communication with relevant authority (Swedish Chemicals Agency, KEMI).

4. *Danish Product Register* (DPR, 2015). As with the Swedish Product Register, all substances under the industry NACE code C17: “Manufacture of paper and paper products” and UCN codes related to paper (see Appendix B1 for details) were retrieved. Obtained substance lists included CAS number for each of the substances, number of preparations a substance is used in and the total mass (tonnes) of the substance used in the selected industrial sector. Due to confidentiality, only limited quantitative information was available for substances retrieved using UCN codes. Information was retrieved through personal communication with relevant authority (Danish Working Environment Authority).
5. *Norwegian Product Register* (NPR, 2015). As with the Swedish and Danish Product Registries, all substances under the industry NACE code C17: “Manufacture of paper and paper products” and UCN codes related to paper (see Appendix A for details) were retrieved. Obtained substance lists included CAS number for each of the substances, number of preparations a substance is used in and the total mass (tonnes) of the substance used in the selected industrial sector. Due to confidentiality, only limited quantitative information was available for substances retrieved using UCN codes. Information was retrieved from SPIN (Substances in Preparations in Nordic Countries, <http://www.spin2000.eu>) database and through personal communication with relevant authority (Norwegian Environment Agency).
6. *Swiss national law on materials and articles intended to come into contact with food* (FDHA, 2005). Swiss national law (ordinance) has entered into force in 2010 and was revised for the last time in May 2017. Among other, the piece of legislation contains a list of substances to be permitted (“positive list”) for use in printing inks for food packaging. The legislation focuses on printing inks used in food packaging, but not in direct contact with food and does not distinguish between materials that printing inks can be applied to (e.g. paper, metal).
7. *German (draft) ordinance on printing inks* Draft Twenty-First Ordinance amending the Consumer Goods Ordinance – Notified version (BMEL, 2016; www.bmel.de). In 2016, Germany has drafted and proposed to the European Commission an ordinance on printing inks. Proposed legislation would apply to printing inks and printing varnishes applied on both the food-contact and non-food-contact sides of food packaging. Similarly to the Swiss legislation, German draft ordinance included a “positive” list of substances (colorants, solvents, photo initiators and other additives). In response to the German proposal, the EU informed the competent authorities that a harmonised legislation across the EU was planned to be adopted in 2018.
8. Inventory list of the European Printing Inks Association (EUPIA, 2013), comprising packaging ink raw materials applied to the non-food contact surface of food packaging (www.eupia.org). The EUPIA published an inventory of all substances used in the manufacturing of food packaging inks in the European Union (EU). Printing inks and varnishes for food packaging are used in a variety of printing techniques on different substrates, in particular:
 - Rotogravure and flexographic printing. Commonly applied on flexible films, aluminium foil, paper and cardboard.
 - Offset printing. Commonly applied on paper, cardboard, rigid plastics and metal.

- Screen printing. Commonly applied on rigid plastics, films, foil and metals.
- Roller coating on metal.
- Digital inks. Commonly applied on paper, cardboard, flexible films and aluminium foils.
- Jet inks. Commonly applied on paper, flexible film, aluminium foils and rigid plastics.

As with the “positive” lists mentioned above, inventory provided by EUPIA did not concern paper or cardboard printing in particular, however, share of paper and cardboard in the European food packaging was expected to be substantial (see Figure 21 for details). For the purpose of this report, latest version of the inventory was used (published December 2013).

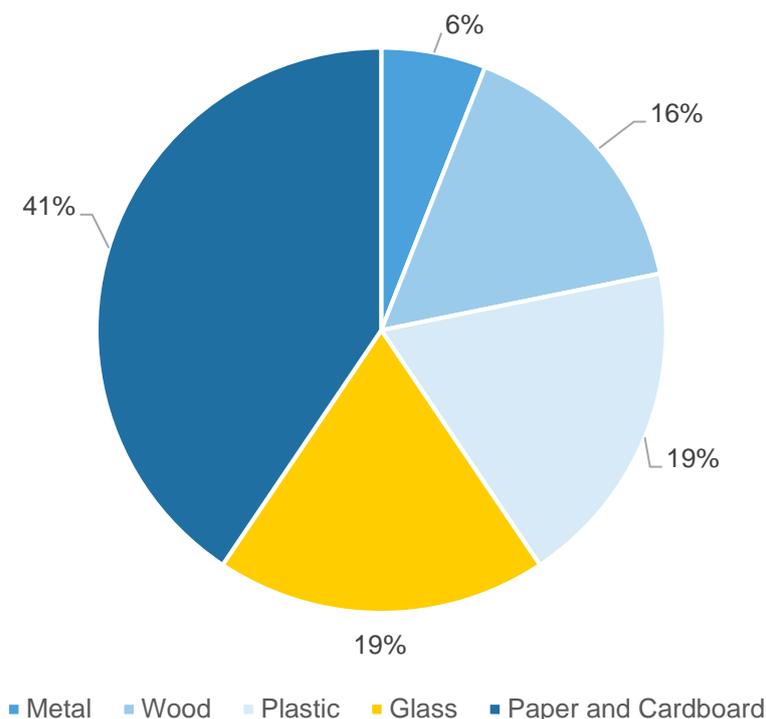


Figure 21. Shares of packaging waste generation by material in 2014, EU-28 (www.ec.europa.eu).

9. *European Food Safety Authority* (EFSA, 2012) report on non-plastic Food Contact Materials (<http://www.efsa.europa.eu>). EFSA scientific cooperation (ESCO) working group was set up with the goal of collecting information from the EU member states on use of substances in food contact materials. The group focused on non-plastic materials (paper, board, rubber, wood, etc.) and substances for which no harmonised risk assessment was available. Lists of substances from selected member states were compiled and submitted to EFSA for overall compilation. The lists were primarily based on national legislation concerning food contact materials or recommendations towards industrial practices. As the scientific output of the working group, an inventory of 2800 substances used in production of variety of food contact materials was published in 2012. List of substances used for the manufacture of paper and board was used in the present work.
10. *Inventory of the Danish printing industry*, part of a project carried out by the Danish Environmental protection Agency (Danish EPA, 2011). Triggered by the implementation of the EU REACH regulation the Danish EPA carried out a study aiming at identification of substances used by the Danish printing industry. The final

report provided results of the combined search of almost 900 material safety datasheets provided by 15 Danish printing houses. The resulting inventory covers off-set, screen and flexo printing, and did not focus on a specific material printing can be applied on. Some indications on potential functions of substances in printing processes were also provided.

11. *Chemical additives for the production of pulp and paper* (Zellcheming, 2008). A book published by the Association of Chemical Pulp and Paper Chemists and Engineers (Weiterstadt, Germany; ISBN 978-3-86641-120-3) on use of chemicals in the production of pulp and paper. While the publication did not provide an explicit inventory of substances used in the production process, examples of chemicals and substances used, as well as their function in the production process were mentioned throughout the book. The book did not have a clear geographical scope, hence all the substances derived from it were reported as “International”.

A1.2. Prioritisation

Prioritisation of most relevant paper and paperboard

To identify the paper grades that were of most interest, a prioritisation model was developed and applied. The two parameters, in the model, were:

- i. Quantities on the Swedish market (see Section 3.1)
- ii. Exposure scenario (see Table 6 and Table 7)

Prioritisation of most relevant substances

A prioritisation model was needed to reduce number of identified substances. The prioritisation model was based on two criteria:

- 1) Geographical relevance;
- 2) Relevance to paper as a material.

Where *geographical relevance*¹¹² was divided into three levels:

- 1) Global/International i.e. outside the EU single market or unknown origin;
- 2) EU/Europe;
- 3) Sweden.

Relevance to paper was also divided into three levels:

- 1) Substances potentially associated with paper;
- 2) Substances identified or quantified in paper;
- 3) Substances documented to be used in paper.

Geographical and paper relevance factors (1-3) were assigned to each category. Project relevance factor (1-9) represents mathematical product of geographical and paper relevancies. Based on project relevance factor, three relevance levels were defined: Low (<3), Medium (3-

¹¹² The levels of geographical relevance were based on the result from origin of quantities on the Swedish market (see Section 3.1).

6), High (>6). Depending on the level of relevance, different amount of information was provided for each of the substances.

A1.3. Identification of paper articles and substances

Identification of linkage between paper articles, pulp, chemicals and substances

This linkage was performed by identifying high priority substances, literature studies, in-depth interviews with the industry and chemical expertise.

Identification of potential contaminants and impurities

Substances identified in the experimental literature, but not present on product registry lists (for Sweden, Denmark and Norway) and ECHA list were classified as potential contaminants.

In-depth interviews with industry

Interviews with actors in the Swedish pulp and paper industry were conducted to get a deeper overview of the substances used in paper article manufacturing and their presence in the final paper article. In, addition, to further target specific substances and their presence in paper articles, a list with identified “high” relevance substances (listed in Appendix B1) was sent to the industry to complement with relevant information for the “high” priority list.

The questions were designed to obtain information on substances used in paper article manufacturing and their occurrence in the final paper material (e.g. softening agents, anti-foaming agents, biocides, flame retardants, pigments, water repellent treatments, binders, fixing agents, antioxidants, aromas and scent-reduction agents). Furthermore, questions were asked to see if they followed any legislations and had internal guidelines on measuring substance concentrations in their final paper material.

Predicted functions of chemicals and prediction of non-CAS substances

- | | | |
|------------------------|---------------------|----------------------|
| 1. Wet strength | 13. Dye | 25. Antioxidant |
| 2. Sizing agent | 14. Pigment | 26. Stabiliser |
| 3. Rheology modifier | 15. Dry strength | 27. Solvent |
| 4. Retention aid | 16. Release agent | 28. Film former |
| 5. Anti-foaming | 17. Fixatives | 29. Tackifier |
| 6. Surfactant | 18. Printing aid | 30. Photo-initiators |
| 7. Water treatment | 19. Plasticizer | 31. Perfume |
| 8. Adhesion promoter | 20. Printing ink | 32. Preservative |
| 9. Deinking | 21. Chelating agent | 33. Cross-linker |
| 10. Bleaching | 22. pH regulator | 34. Cleaning agent |
| 11. Biocide | 23. Lamination | 35. Water repellent |
| 12. Optical Brightener | 24. Mineral fillers | 36. Biopolymer |

The list of 36 defined functions was used to predict the function of the substances without any CAS- number i.e. the non- CAS substances (822 substances). These substances were grouped into families of chemicals with specific functions and also into categories process, functional or coating chemical.

Furthermore, it is important in terms of risk assessment to identify if a chemical is embedded (bonded) or non-embedded (non-bonded).

In the predictions, the chemicals were classified into category of chemicals where they had similar function. To be able to do these predictions, the substances and their usage were categories according to below (1-5). For results, see Appendix B1.

1. **Fatty acid and derivatives** belong to the functional additives used as moisturizer, skin conditioner, skin softener and make paper water resistant. They usually comprise of long alkyl chains where by varying the chain length may result into a new chemical. Many of the long chain fatty acids may also be present in the wood raw-material and may arise as contaminant.
2. **Fatty alcohol and esters** belong to both process and functional chemicals where their main function is as emulsifier, emulsion stabiliser and surfactants. Fatty alcohols are used as anti-foamer as process chemical.
3. **Unknown chemicals** can arise as contaminants from the intermediates that are used in the synthesis. Examples can be residual monomers from the polymer dispersions used, intermediates used for the synthesis of dyes or the impurities present in the natural oils and extractives that are used as perfumes.
4. **Perfumes** include a large number of chemicals originating from natural oils of different origin, sesquiterpenes and a number of aromatic compounds. All such compounds are usually used in skin care towels. All the perfumes can give rise to contaminants in the paper articles.
5. **Sizing/Coating:** Coatings are always considered to form films whereas sizings do not form films on the surface but instead diffuse into the substrate. Based on these basic differences selection of additives, pigment and dyes and polymeric binders are different.
5. **Printing inks/Coating:** Comprises of binders, pigments and other additives to control rheology and curing/drying properties. Printing inks, in general use more dyes compared to pigments. The main difference between the groups are the rheological, drying/ curing additives.

A2. Delimitations

Exposure scenarios

The exposure scenarios for the older age group, i.e. adults, adolescents and children above three years old, were used for comparison of consumer exposures to different paper and board materials and are not suitable for detailed risk assessment. No available study on exposure to paper and board articles was found for this age group.

Since “other papers and boards” include such a large variety of articles, it was not possible to develop exposure scenarios that cover this material category.

Statistical data

The data from Swedish Forests Industries Federation and Statistics Sweden had not been compiled in the same manner. The data from Statistics Sweden included both materials and articles, and the data from Swedish Forests Industries Federation was based on collected data from the industry. Hence, the data was valid for both cases but the Statistics Sweden data considering import and export also included articles registered at custom duties. Since the data was collected from various sources (Statistics Sweden and Swedish Forests Industries Federation), the data had to be correlated when used in the same comparison.

Non-apparent consumption of paper in Europe

Paper and paperboards that reached Sweden with imported articles, e.g. packaging, had not been documented by Statistics Sweden. Hence, there was no official statistic available on

import of this paper flow. Available literature sources suggested that most of the imported paper that follows incoming articles were case material or cartonboard, as well as graphic papers used for manuals and other documentation which were included in the product packaging. Pivnenko et al. (2016) estimated that 5.8 million tonnes of paper were imported into EU from third country for the so-called “non-apparent” consumption. This represented approximately 7.5% of all the paper consumption in Europe in 2012¹¹³. These amounts were rather uncertain, but could be expected to increase due to increasing international shipping of goods. Due to lack of reliable data, it was assumed that non-apparent paper consumption through import of packaging materials in Sweden was similar to Europe¹¹².

EU import could include articles that had been transported to EU from non-EU countries and then get registered as import from EU countries¹¹⁴.

Market survey

Swedish Forest Industries Federation represented almost all paper and pulp mills in Sweden apart from one mill (Crane Tumba).

Uncertainty

Two types of uncertainty were identified and both caused delimitations in the projects.

The uncertainties were separated into: 1) Probability of a substance being used during manufacturing of paper and paperboard articles in Sweden; 2) Uncertainty related to the quantity of a substance being present in paper and paperboard. The first type of uncertainty, which was related to the use of substances, was reduced by applying the prioritisation of substances methodology described in Section 3.3.1 and in this Appendix. Regarding the second type of uncertainty, uncertainty of the quantity of a substance in the final paper article, this uncertainty was approached by identifying levels in literature or making assumption of the quantity based on literature data. This type of uncertainty is presented in Appendix B1.

Data from Swedish product register

The project received anonymised data the Swedish product registered. The 458 substances only consisted of 24% of the total number of substances in SPR’s register, but it equalled 94% of the total registered volume.

¹¹³ Pivnenko et al. 2016a

¹¹⁴ Personal communication with Statistics Sweden 2017

A3. Import and export

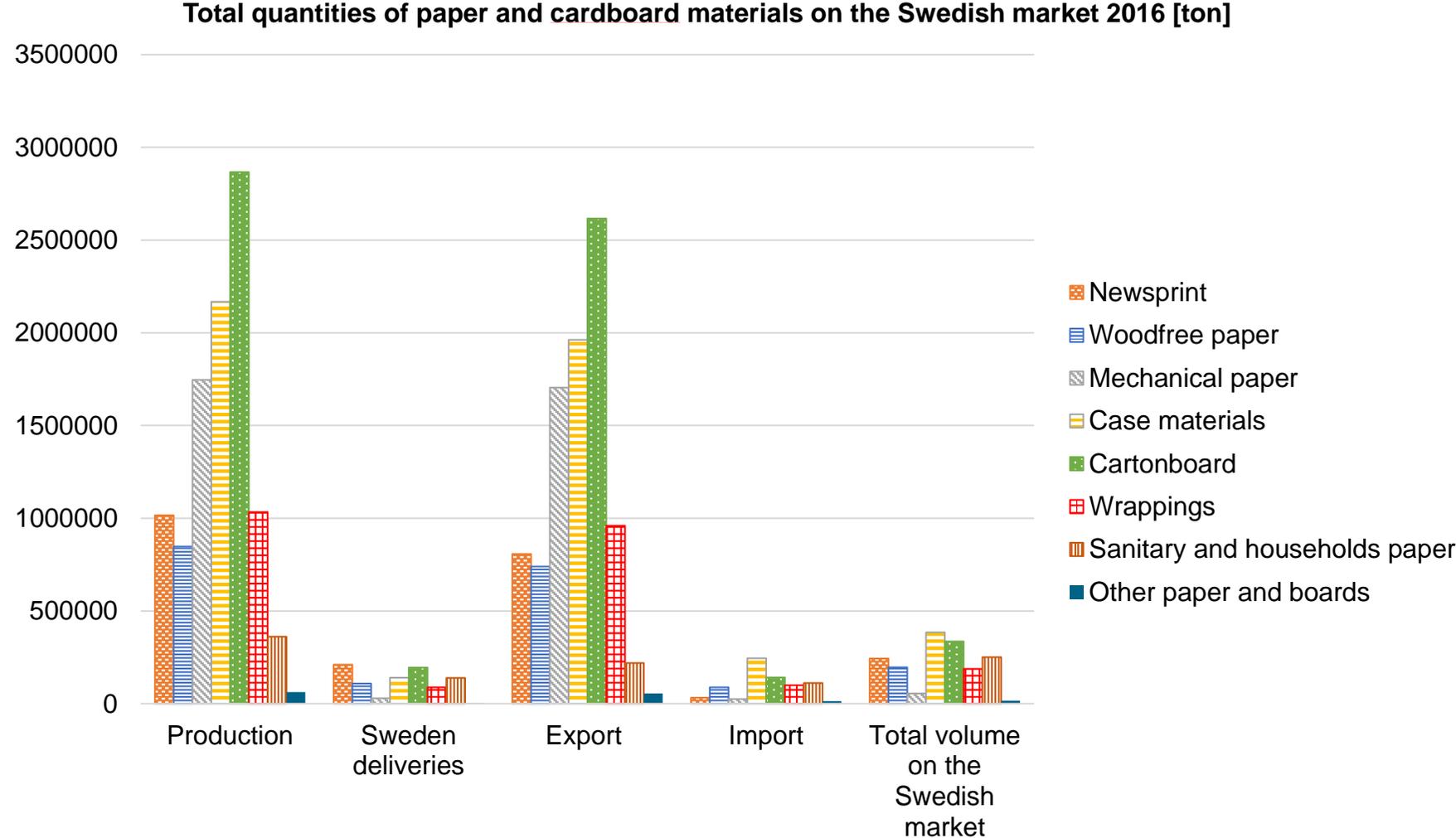


Figure 22. Import and export on the Swedish market.

B1. Priority substances

[See separate excel sheet](#)

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B1.2. UCN codes

Table 14. Used categories Nordic (UCN) codes and their description

UCN code	Description
B15330	Fibre, leather, rubber and polymerised materials preservatives (PT9)
G12300	Calendring agents
I05200	Paper impregnation agents
O27100	Surface treatment for paper, cardboard and other non-metals
R30900	Raw materials for production of paper
S10300	Carbon paper
S10400	Self-copying paper
T15111	Printing inks Water base Letterpress printing Paper/cardboard/paperboard
T15121	Printing inks Water base Rotogravure Paper/cardboard/paperboard
T15131	Printing inks Water base Flexocolour (aniline dye) Paper/cardboard/paperboard
T15141	Printing inks Water base Offset printing Paper/cardboard/paperboard
T15151	Printing inks Water base Serigraphic printing Paper/cardboard/paperboard
T15171	Printing inks Water base Other Paper/cardboard/paperboard
T15211	Printing inks Based on organic thinner Letterpress printing Paper/cardboard/paperboard
T15221	Printing inks Based on organic thinner Rotogravure Paper/cardboard/paperboard
T15231	Printing inks Based on organic thinner Flexocolour (aniline dye) Paper/cardboard/paperboard
T15241	Printing inks Based on organic thinner Offset printing Paper/cardboard/paperboard
T15251	Printing inks Based on organic thinner Serigraphic printing Paper/cardboard/paperboard
T15271	Printing inks Based on organic thinner Other Paper/cardboard/paperboard
T15311	Printing inks No thinner Letterpress printing Paper/cardboard/paperboard
T15321	Printing inks No thinner Rotogravure Paper/cardboard/paperboard
T15331	Printing inks No thinner Flexocolour (aniline dye) Paper/cardboard/paperboard
T15341	Printing inks No thinner Offset printing Paper/cardboard/paperboard
T15351	Printing inks No thinner Serigraphic printing Paper/cardboard/paperboard
T15371	Printing inks No thinner Other Paper/cardboard/paperboard
T15411	Printing inks Powder Letterpress printing Paper/cardboard/paperboard
T15421	Printing inks Powder Rotogravure Paper/cardboard/paperboard
T15431	Printing inks Powder Flexocolour (aniline dye) Paper/cardboard/paperboard
T15441	Printing inks Powder Offset printing Paper/cardboard/paperboard
T15451	Printing inks Powder Serigraphic printing Paper/cardboard/paperboard
T15471	Printing inks Powder Other Paper/cardboard/paperboard
T15511	Printing inks Hardener to printing inks Letterpress printing Paper/cardboard/paperboard
T15521	Printing inks Hardener to printing inks Rotogravure Paper/cardboard/paperboard
T15531	Printing inks Hardener to printing inks Flexocolour (aniline dye) Paper/cardboard/paperboard
T15541	Printing inks Hardener to printing inks Offset printing Paper/cardboard/paperboard
T15551	Printing inks Hardener to printing inks Serigraphic printing Paper/cardboard/paperboard
T15571	Printing inks Hardener to printing inks Other Paper/cardboard/paperboard
T15611	Printing inks Additive to printing inks Letterpress printing Paper/cardboard/paperboard
T15621	Printing inks Additive to printing inks Rotogravure Paper/cardboard/paperboard
T15631	Printing inks Additive to printing inks Flexocolour (aniline dye) Paper/cardboard/paperboard
T15641	Printing inks Additive to printing inks Offset printing Paper/cardboard/paperboard
T15651	Printing inks Additive to printing inks Serigraphic printing Paper/cardboard/paperboard
T15671	Printing inks Additive to printing inks Other Paper/cardboard/paperboard

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