ISSN 1831-9424

European Commission

JRC SCIENCE FOR POLICY REPORT

Revision of EU Ecolabel criteria for Absorbent Hygiene Products and Reusable Menstrual Cups (previously Absorbent Hygiene Products)

Preliminary Report

Pérez-Camacho, M. N., Faraca, G., Pérez Arribas, Z., Kowalska, M. A., Wolf, O. (JRC B.5 - Circular Economy and Sustainable Industry)

Sinkko, T., Tosches D. (JRC D.3 - Land Resources and Supply Chain Assessments)

November 2023

Joint Research Centre

EUR 31761 EN

This publication is a Science for Policy report by the Joint Research Centre (JRC), the European Commission's science and knowledge service. It aims to provide evidence-based scientific support to the European policymaking process. The contents of this publication do not necessarily reflect the position or opinion of the European Commission. Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use that might be made of this publication. For information on the methodology and quality underlying the data used in this publication for which the source is neither Eurostat nor other Commission services, users should contact the referenced source. The designations employed and the presentation of material on the maps do not imply the expression of any opinion whatsoever on the part of the European Union concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

EU Science Hub
https://joint-research-centre.ec.europa.eu

JRC134703

EUR 31761 EN

PDF ISBN 978-92-68-09961-2 ISSN 1831-9424 doi:10.2760/467041 KJ-NA-31-761-EN-N

Luxembourg: Publications Office of the European Union

© European Union, 2023

The reuse policy of the European Commission documents is implemented by the Commission Decision 2011/833/EU of 12 December 2011 on the reuse of Commission documents (OJ L 330, 14.12.2011, p. 39). Unless otherwise noted, the reuse of this document is authorised under the Creative Commons Attribution 4.0 International (CC BY 4.0) licence (https://creativecommons.org/licenses/by/4.0/). This means that reuse is allowed provided appropriate credit is given and any changes are indicated.

For any use or reproduction of photos or other material that is not owned by the European Union permission must be sought directly from the copyright holders. The European Union does not own the copyright in relation to the following elements:
- Cover page illustration, images #347775264, #111232582, and #121922416, 2023. Source: stock.adobe.com
- Page 22, Figure 2, images #277059632, #336786018, #229278127, and #239511058. Source: stock.adobe.com

How to cite this report: Pérez-Camacho, M. N., Faraca, G., Pérez Arribas, Z., Kowalska, M. A., Wolf, O, Sinkko, T., Tosches D., *Revision of EU Ecolabel criteria for Absorbent Hygiene Products and Reusable Menstrual Cups (previously Absorbent Hygiene Products), Preliminary Report,* Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/467041, JRC134703.

Contents

Abstract

This Preliminary Report is intended to provide the background information for the revision of the EU Ecolabel criteria for the product group 'Absorbent Hygiene Products'. The previous set of criteria was adopted in 2014 through Commission Decision 2014/763/EU. The revised EU Ecolabel criteria are set to cover a wider scope as for the first time they include a set of criteria targeting reusable menstrual cups. The product group has been enlarged thus to cover 'absorbent hygiene products' and 'reusable menstrual cups'.

To support the revision process with technical evidence, this Preliminary Report consists of:

- an analysis of the scope, definitions and description of the legal framework, as well as a first proposal for the revised scope (Task 1);
- a market analysis (Task 2);
- a technical analysis, including an environmental assessment (Task 3).

This background information, combined with input received from the stakeholders involved, has been used in the revision process to justify the choices behind the revision of the criteria.

Executive summary

This report provides the initial input for the revision of the EU Ecolabel criteria for absorbent hygiene products as well as information to substantiate the new criteria for reusable menstrual cups.

The JRC collects and analyses the scientific evidence necessary for the implementation of product-specific EU Ecolabel criteria under the EU Ecolabel Regulation (Regulation (EC) 66/2010)[1]. According to Annex I to that Regulation, this scientific evidence is used in a multistep procedure, starting with the preparation of this Preliminary Report which contains the technical assessment of the respective sector and product group. On that basis, a set of criteria for an improved environmental performance is developed in close co-operation with stakeholders from industry, NGOs, academia and Member States.

The content of this Preliminary Report consists firstly of an analysis of the scope of the product group under revision, accompanied by definitions and a description of the legal framework which concludes with a proposal for a revised scope (Task 1). It is followed by a market analysis (Task 2) and ends with a technical analysis of the main innovations in absorbent hygiene products, including an environmental assessment carried out using the PEF method for representative products under the scope (Task 3).

The EU Ecolabel, the official voluntary labelling scheme of the EU, promotes the production and consumption of products (goods and services) with a reduced environmental impact over their life cycle, and is aimed at identifying products with an excellent environmental performance. Established in 1992, it has become a key policy instrument within the European Commission's Sustainable Consumption and Production and Sustainable Industrial Policy (SCP/SIP) Action Plan (COM(2008) 397) and the Roadmap for a Resource-Efficient Europe (COM/2011/0571). The EU Ecolabel was mentioned as having an important role in the new Circular Economy Action Plan (CEAP) from March 2020.

The EU Ecolabel was also mentioned in the chapeau Communication on making sustainable products the norm. This Communication[2] accompanies a package of measures proposed in the CEAP and adopted on 30 March 2022[3], including: a proposal for the Ecodesign for Sustainable Products Regulation, an EU strategy for sustainable and circular textiles, a proposal for a revised Construction Products Regulation, and a proposal for empowering consumers in the green transition. The Communication mentions the EU Ecolabel as an important tool whose criteria will be developed in synergy with future Ecodesign measures.

An assessment of the scope extension (Task 1) for several reusable products was carried out using a traffic light system. This assessment showed that reusable menstrual cups had potential for inclusion given their market demand and potential for environmental improvement. The market analysis (Task 2) concluded that the market share of disposable Absorbent Hygiene Products (AHPs) is high and continues to grow exponentially, as does the market of reusable options. The technical analysis (Task 3) was performed to learn about innovations in the field of AHPs and also to obtain the background information to develop criteria for reusable products. The analysis of the environmental hotspots using the Product Environmental Footprint (PEF) methodology identified as such the production of raw materials for AHPs, while for the reusable menstrual cup the hotspots are related to the use phase. At the initial stage of the revision process, it was suggested that production of raw materials (fibres and plastics) should be examined, while a criterion on packaging was also proposed.

[1] Regulation (EC) No 66/2010 of the European Parliament and of the Council of 25 November 2009 on the EU Ecolabel, OJ L 27, 30.1.2010, p. 1–19, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32010R0066

[2] COM (2022) 140 COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS On making sustainable products the norm, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52022DC0140

[3] Circular economy action plan, https://ec.europa.eu/environment/strategy/circular-economy-action-plan_en

1 Introduction

The objective of this project is to revise the existing EU Ecolabel criteria (Commission Decision 2014/763/EU[4]) for Absorbent Hygiene Products (AHPs). The criteria were adopted for the first time in 2014 and the Decision currently in force is valid until the end of December 2023.

This Preliminary Report is intended to provide the background information for the revision of the EU Ecolabel criteria for AHP. The study has been carried out by the European Commission's Joint Research Centre (JRC), Unit B.5 – Circular Economy and Sustainable Industry with technical support for the Product Environmental Footprint analysis from Directorate D.3, Land Resources and Supply Chain Assessments (JRC-ISPRA). The work is being developed for the European Commission's Directorate General for the Environment.

An important part of the process for developing or revising EU Ecolabel criteria is the involvement of stakeholders through consultation exercises and invitation to working group meetings. This document provides the background information required for the first Ad-hoc Working Group (AHWG) meeting, which took place on the 14 October 2021.

This preliminary report addresses the requirements of the EU Ecolabel Regulation No 66/2010[2] for technical evidence to inform criteria revision. It consists mainly of the following sections: an analysis of the scope, definitions and description of the legal framework; an economic and market analysis; and an overview of existing technical lifecycle assessment studies, revealing the significant environmental impacts. Combined with input from stakeholders, this information was used to present an initial set of revised criteria proposals (1st Technical Report).

The following chapters analyse the state-of-the-art of the product types included in the scope of the EU Ecolabel criteria, namely: disposable baby diapers, disposable feminine care pads, tampons and disposable nursing pads (also known as breast pads). An assessment of reusable alternatives compared to the disposable products currently in scope is also presented. The following aspects have been investigated:

- an analysis of the scope, definitions and description of the legal framework, European standards, other voluntary schemes, as well as a first proposal for a revised scope (Task 1);
- a market analysis (Task 2);
- a technical analysis, including an analysis of the environmental hotspots using the Product Environmental Footprint (PEF) methodology (Task 3).

This study was carried out by the Joint Research Centre (JRC). All relevant documents can be found in the dedicated website[5].

[4] Commission Decision of 24 October 2014 establishing the ecological criteria for the award of the EU Ecolabel for absorbent hygiene products (OJ L 320, 6.11.2014, p. 46–63), https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:32014D0763

[5] JRC Product Bureau Website, https://susproc.jrc.ec.europa.eu/product-bureau//product-groups/415/home

2 Task 1: Scope and definition analysis

The aim of task 1 of this Preliminary Report is to provide background information supporting the revision of the current scope and definitions included in the EU Ecolabel criteria for Absorbent Hygiene Products. The assessment is based on the information from the previous revision process (section 2.2), the regulatory and policy framework (section 2.3), the comparison with other ISO 14024 type I ecolabel schemes and initiatives (section 2.3), an overview of the different products categorisations in use in the market (section 2.4), a preliminary market and environmental analysis (section 2.5), and the information collected *via* a stakeholder questionnaire in December 2020 (section 2.6). Task 1 concludes with a proposal for a revised product scope (section 2.7).

2.1 Existing scope and definition

The current EU Ecolabel criteria for Absorbent Hygiene Products defined in Article 1 of Commission Decision 2014/763/EU[3] defines this product group's scope as follows:

1. The product group 'absorbent hygiene products' shall comprise baby diapers, feminine care pads, tampons and nursing pads (also known as breast pads), which are disposable and composed of a mix of natural fibres and polymers, with the fibre content lower than 90 % by weight (except for tampons).

2. The product group shall not include incontinence products and any other type of products falling under the scope of Council Directive 93/42/EEC[6].

The second point of the scope of EU Ecolabel criteria for AHPs refers to the fact that incontinence products are not included in the scope of the EU Ecolabel for AHPs, since incontinence products are covered under the scope of Medical Devices Regulation (2017/745/EC)[7] concerning medical devices. Indeed, according to Article 2 of the EU Ecolabel Regulation[1]: 'This Regulation shall apply neither to medicinal products for human use [...] nor to any type of medical device'.

2.2 Background information

This section presents information which was collected before the start of the revision process. First, it summarises the most important considerations from the discussion on the scope definition in the previous revision. Secondly, it presents the results from a preliminary scope questionnaire, which was sent to stakeholders in December 2020 to analyse the potential interest to expand the existing scope to other reusable absorbent hygiene products.

2.2.1 Input from last revision process

At the time of the vote of the adopted EU Ecolabel criteria for Absorbent Hygiene Products (2014/763/EU)[3], the representatives of the EU Member States requested that, in the occasion of the next revision, the points listed in **Table 1** be further investigated.

[6] Council Directive 93/42/EEC of 14 June 1993 concerning medical devices. OJ L 169, 12.7.1993, p. 1–43, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31993L0042

[7] Regulation (EU) 2017/745 of the European Parliament and of the Council of 5 April 2017 on medical devices, amending Directive 2001/83/EC, Regulation (EC) No 178/2002 and Regulation (EC) No 1223/2009 and repealing Council Directives 90/385/EEC and 93/42/EE. OJ L 117, 5.5.2017, p. 1–175, https://eur-lex.europa.eu/eli/reg/2017/745/oj

Table 1. Content of the Commission statement that accompanied the EU Ecolabel criteria for Absorbent Hygiene Products

Product Group	Points for further investigation
Absorbent Hygiene Products (2014/763/EU)	Evaluate the impact of the criterion establishing social requirements should be assessed in respect of the cost/benefits ratio at the level of the producer and the supply
	Consider a more horizontal approach towards the assessment of the equivalency of alternative certification schemes for fibres
	Consider an increase in the percentage of fibres to be covered by sustainable forestry management certificates
	Re-assess the possibility to develop criteria related to plastic components
	Further investigate the pros and cons of using lotions and fragrances in this product group
	Consider the need for the use of any antimicrobial agent in AHP
	Investigate if a criterion on recyclability of diapers is technically feasible and implementable
	In case within the current validity of the criteria there will be further scientific evidence on the use/effect of isothiazolinones in leave-on products with the purpose of further restrictions in lotions, the Commission will take the appropriate measures to reflect such changes in the current criteria chain

Source: Summary of the meeting of the Regulatory Committee established under Article 16 of Regulation (EC) 66/2010 of 25 November 2009 of the European Parliament and of the Council on the EU Ecolabel, 2014.

In the previous revision process for EU Ecolabel criteria for AHPs, the Preliminary Report (Cordella et al., 2013) discussed the possibility of including reusable textile alternatives in the scope of this product group. However, it concluded that reusable textile alternatives should not be part of the scope since '*textile products for interior use consisting of at least 90% by weight of textile fibres*' are included in this label, i.e. the EU Ecolabel for textile products. The Preparatory Study on Textile Products in line with the proposal of the Ecodesign for Sustainable Product Regulation (ESPR)[8] will provide further insights on the possible inclusion of reusable textile alternatives under its scope[9].

2.3 Legal instruments and environmental schemes of relevance

Absorbent hygiene products (excluding incontinence products) are not subject to sector-specific EU legislation. Their safety requirements are covered by several general pieces of horizontal EU legislation applicable to multiple consumer goods. The main regulatory and policy framework which appears relevant for the product group is briefly described in this section.

2.3.1 Main Regulatory framework

2.3.1.1 Absorbent Hygiene Products

EU Ecolabel Regulation

Revision of the EU Ecolabel criteria for Absorbent Hygiene Products relies mainly on EU Ecolabel Regulation (EC) 66/2010. The Regulation shapes how the criteria are examined and defines the processes and principles by which they must be developed. Article 6 within this Regulation sets out the following general requirements for criteria development:

---

[8] Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC. COM/2022/142 final, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022PC0142&qid=1678360776030

[9] Home page of the Preparatory Study on Textile Products https://susproc.jrc.ec.europa.eu/product-bureau//product-groups/467/home

- It shall cover the most significant environmental impacts, in particular the impact on climate change, the impact on nature and biodiversity, energy and resource consumption, generation of waste, emissions to all environmental media, pollution through physical effects and use, and release of hazardous substances.
- It shall encourage reduction of hazardous substance use by: (1) substitution of hazardous substances by safer substances; (2) use of alternative materials, design or technologies which eliminate the need for hazardous substances, wherever technically feasible.
- The potential to reduce environmental impacts due to durability and reusability of products shall be proved.
- The net environmental balance between the environmental benefits and burdens shall be covered, including health and safety aspects, at the various life stages of the products.
- Where appropriate, social and ethical aspects shall be covered as well, e.g. by referencing to related international conventions and agreements, such as relevant ISO standards and codes of conduct.
- To enhance synergies, criteria established for other environmental labels shall be considered, particularly labels that are officially recognised (nationally or regionally) and ISO 14024 type I ecolabels where they exist for that product group.
- As far as possible, the principle of reducing animal testing shall be addressed.

More specifically, Article 6(4) requires that EU Ecolabel 'fitness for use' criteria shall also be included. Additional provisions are made in Articles 6(6) and 6(7) regarding the substances contained in the product. Accordingly, the EU Ecolabel shall not be awarded to products containing the following:

- Substances or preparations/mixtures meeting the criteria for classification as toxic, hazardous to the environment, carcinogenic, mutagenic or toxic for reproduction (CMR), in accordance with Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging (CLP) of substances and mixtures.
- Substances referred to in Article 57 of 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), establishing a European Chemicals Agency.
- Substances or preparations/mixtures that have been identified according to the procedure described under Article 59 of the REACH Regulation No 1907/2006 and which have been subsequently classified as Substances of Very High Concern.

Article 6(7) allows derogations for substances only if it is not technically feasible to substitute them with safer chemicals, or obviate the need for the substance by using alternative materials or designs, or products which have a significantly higher overall environment performance compared with other goods of the same category. However, no derogation shall be given for substances that:

- meet the criteria of Article 57 of Regulation (EC) No 1907/2006;
- are identified according to the procedure described in Article 59(1) of that Regulation;
- present in mixtures, in an article or in any homogeneous part of a complex article in concentrations higher than 0.1 % (weight by weight).

Regulation 1907/2006/EC of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency (ECHA)

REACH places responsibility on industry to manage the risks that chemicals may pose to human health and the environment, as well as to provide safety information that would be passed down the supply chain. The companies that do not undertake this procedure will not be able to produce, sell or use their products and would consequently be forced to stop their activity. The Regulation is complementary to other environmental and safety legislation but does not replace sector-specific legislation (for example, legislation on cosmetics or medical devices). REACH does not allow marketing of a chemical substance if it does not have appropriate registration, which has to be carried out by every legal entity that manufactures or imports from outside the European Union substances on their own, in preparations or in articles in quantities of 1 tonne or above per year.

In addition to registration, REACH regulates other procedures such as the management of the risk and hazardous properties of the substance, authorisation of substances of very high concern (SVHC) such as those that are carcinogenic, mutagenic and/or toxic for reproduction, persistent, bio-accumulative and toxic or very persistent and very bio-accumulative and the restriction on the manufacturing, placing on the market and use of certain dangerous substances, preparations and articles when an unacceptable risk to human health or the environment exists. Currently, there are 219 substances registered on the SVHC candidate list and 54 substances subject to authorisation (EU REACH Annex XIV Authorisation List).

Raw material suppliers and other parties involved in the supply chain of AHPs must ensure compliance with this regulation as for instance they may be requested to provide information on the material category under the REACH Regulation, i.e., substance, mixture or article. Parties involved could also be requested to provide technical specifications, including a product data sheet and a brief history of the materials used in AHPs. Indications as to whether the material was developed specifically/mainly for AHPs and/or has been used in AHPs in the past could also be demanded.

Regulation 2008/1272/EC on classification, labelling and packaging of substances and mixtures (CLP)

The Regulation aims to ensure a high level of protection of human health and the environment, as well as the free movement of chemical substances, mixtures and certain specific articles, whilst enhancing competitiveness and innovation. In line with the GHS standard, CLP allows for the identification of hazardous chemicals and the communication of these hazards to users through labelling. It also provides the basis for safety data sheets (SDS) regulated under the REACH Regulation, and sets requirements for the packaging of hazardous chemicals.

As within the REACH Regulation, raw material suppliers and manufacturers of AHPs must comply with any hazard classification (including hazard statement) under the CLP Regulation and the Globally Harmonized System of Classification and Labelling (GHS).

Regulation 2012/528/EC concerning the making available on the market and use of biocidal products

The purpose of this Regulation is to improve the functioning of the internal market through the harmonisation of the rules on the making available on the market and the use of biocidal products, whilst ensuring a high level of protection of both human and animal health and the environment.

AHPs must follow the legal provisions of the Biocidal Regulation as finished AHPs are considered to be articles whose safety requirements are covered by the general ('horizontal') EU legislation applicable to multiple consumer goods including the General Product Safety Directive and REACH Regulation.

Regulation (EU) 2023/988 of the European Parliament and of the Council of 10 May 2023 on general product safety

This regulation establishes essential requirements for consumer products that are not covered by sector-specific legislation to protect consumer health and safety and to ensure the proper functioning of the internal European market. The Directive provides a generic definition of a safe product, namely that products must be safe under normal or reasonably foreseeable conditions of use by consumers. Products must comply with this definition. If there are no specific national rules governing the safety of a product, then the safety of a product is assessed in accordance with: European standards pursuant to the product, then Community technical specifications, then Codes of good practice, then State-of-the-art and consumer expectations.

This regulation amended Regulation (EU) No 1025/2012 of the European Parliament and of the Council and Directive (EU) 2020/1828 of the European Parliament and the Council, and repealed Directive 2001/95/EC of the European Parliament and of the Council and Council Directive 87/357/EEC.

According to this Directive, manufacturers of AHPs placed on the market must ensure that their products are safe.

Waste Framework Directive

The Waste Framework Directive (2019/1004/EC) sets the basic concepts and definitions related to waste management, such as definitions of waste, recycling, recovery. It explains when waste ceases to be waste and becomes a secondary raw material (so called end-of-waste criteria), and how to distinguish between waste and by-products. The Directive requires that Member States adopt waste management plans and waste prevention programmes. In order to comply with the objectives set by the Directive, and move towards a

European recycling society with a high level of resource efficiency, Member States shall take the necessary measures designed to achieve the following targets: by 2025, the reuse and the recycling of municipal waste shall be increased to a minimum of 55%, 60% and 65% by weight by 2025, 2030 and 2035 respectively.

Used Absorbent Hygiene Products are part of the municipal waste (2–3% of municipal solid waste (Dri et al., 2018)); however, recovery or recycling actions for these types of products are still very limited in the European Union. The European List of Waste (Commission Decision 2000/532/EC) provides common terminology for classifying waste across the EU. Codes are assigned in a broad variety of activities or as a basis for waste statistics. The European List of Waste is regularly revised; its latest amendment (Commission Decision 2014/955/EU) was made in 2014. According to the last version of the European List of Waste, Absorbent Hygiene Products are classified as wastes from human or animal healthcare and/or related research: wastes whose collection and disposal is not subject to special requirements in order to prevent infection (classification code 18 01 04). Following the European List of Waste may help manage AHP waste, in line with the basic waste management principles laid down in the Waste Framework Directive, contributing to meet the above-mentioned targets.

Air Quality Framework Directive

Council Directive 96/62/EC on ambient air quality assessment and management describes the basic principles as to how air quality should be assessed and managed in the Member States. It lists the pollutants for which air quality standards and objectives will be developed and specified in legislation.

AHP manufacturing sites must comply with the Air Quality Framework Directive while criteria on emissions such as NOx or CO_2 are established in the EU Ecolabel.

Renewable Energy Directive

Directive 2009/28/EC on the promotion of the use of energy from renewable sources establishes an overall policy for the production and promotion of energy from renewable sources in the EU. It requires the EU to fulfil at least 20% of its total energy needs with renewables by 2020 – to be achieved through the attainment of individual national targets. All EU countries must also ensure that at least 10% of their transport fuels comes from renewable sources by 2020. The Directive specifies national renewable energy targets for each country, taking into account its starting point and overall potential for renewables.

This Directive applies to energy that is consumed in the AHP manufacturing process. The use of renewable sources should be promoted in the production of the final AHPs and in the manufacture of raw materials that become part of the AHPs (e.g. fluff pulp production or silicone production).

The Packaging and Packaging Waste Directive

This Directive (2018/852/EC) aims to prevent or reduce the impact of packaging and packaging waste on the environment. It contains provisions on the prevention of packaging waste, on the reuse of packaging and on the recovery and recycling of packaging waste.

This Regulation applies to AHPs and RMCs as packaging is addressed in the new criteria as outlined in the Technical Reports.

The new proposal for a revision of EU legislation on Packaging and Packaging Waste (COM/2022/677 final)[10] published in November 2022, sets out new recycling and recyclability targets for plastic packaging.

Directive 2019/904/EC on the reduction of the impact of certain plastic products on the environment

This Directive aims to reduce the amount of single-use plastic (SUP) products most often found on Europe's beaches and seas. This initiative focuses on the 10 most found SUP products and fishing gear. Where alternatives are readily available and affordable, single-use plastic products are to be banned from the market. For products without straightforward alternatives, the focus is on limiting their use through a national reduction in consumption; design and labelling requirements and waste management/clean-up obligations for producers.

[10] Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive (EU) 2019/904, and repealing Directive 94/62/EC https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022PC0677

From 3 July 2021, according to Directive (EU) 2019/904, EU Member States shall, through their national legislation, ensure that certain single-use plastic products which are placed on their market bear a marking on the packaging or product itself. The marking concerns single-use plastic products listed in Part D of the Annex to Directive (EU) 2019/904. Sanitary towels (pads), tampons and tampon applicators are part of these products. The marking will have to follow rules laid down by the Commission Implementing Regulation, of 17 December 2020, on harmonised marking specifications on single-use plastic products listed in Part D of the Annex to Directive (EU) 2019/904. The standardised labelling will indicate how waste should be disposed of, the negative environmental impact of the product, and the presence of plastic in the products. This will apply to sanitary towels and tampons (European Commission, 2018). **Figure 1** shows the printed marking that sanitary pads and tampons must show on their packaging. The marking illustration must be placed on the primary packaging of sanitary towels (pads) and tampons, with the surface area 10 cm^2 or more as Annex I to the Commission Implementing Regulation of 17 December 2020 explains among other graphic requirements.

Figure 1. Printed marking that sanitary pads and tampons must show on their packaging

Source: Commission Implementing Regulation, of 17 December 2020, on harmonised marking specifications on single-use plastic products.

Medical Devices Regulation

Regulation (EU) 2017/745 of the European Parliament and of the Council of 5 April 2017 on medical devices amends Council Directive 93/42/EEC includes incontinence products in its scope and as a result is relevant to AHPs since incontinence products may at first be categorised as absorbent hygiene products.

However, incontinence products cannot be part of the product group of AHPs because they fall under the Medical Devices Regulation. Thus, incontinence products bearing the CE mark do not have the possibility to obtain the EU Ecolabel at the same time. In fact, after consultation and several internal discussions, it was confirmed that CE-marked absorbent incontinence products could not be included in the scope of the revision of the EU Ecolabel for AHPs unless an amendment was made to Article 2.2 of the EU Ecolabel, which was not an option at this stage of the AHP project.

Communication from the European Commission on EU Policy Framework on biobased, biodegradable and compostable plastics

The European Commission recently published a policy framework aiming to contribute to a more sustainable plastic economy. The 'Communication from the EC - EU policy framework on biobased, biodegradable and compostable plastics'[11] indicates that a possible alternative aligned to reduce GHG emissions, waste generation, littering and derived pollution from fossil-based and non-biodegradable plastics (currently dominant) could be the use of biobased plastics, but considering their whole life cycle. This Communication aims to fill possible gaps and does so by setting orientations to be used by EU policies addressing these plastics in the future.

Biobased plastics (BBP) and biodegradable and compostable plastics (BDCP) have been highlighted as having the potential to have advantages over fossil-based, non-biodegradable plastics. However, the effective sustainability of BBP and BDCP compared to conventional plastics needs to be carefully assessed.

[11] European Commission, 2022. Communication from the EC on EU Policy Framework on biobased, biodegradable and compostable plastics. Available at: https://environment.ec.europa.eu/publications/communication-eu-policy-framework-biobased-biodegradable-and-compostable-plastics_en

2.3.1.2 Reusable menstrual cups

At the moment, there is no global regulatory framework for menstrual products (pads, tampons and menstrual cups). There are a number of countries that are starting to develop standards for menstrual products. In this direction, Austria is working on defining quality criteria for all kinds of female hygiene products at a national level. These criteria aim at safety aspects of the products and will be part of a collection of standards that is used as a guidance document by the food industry (Communication with VKI, Austria). Additionally, the Swedish Institute for Standards (SIS) put forward a proposal to have a global ISO standard for menstrual products (SIS, 2020) and a Technical Committee was created in 2022 as ISO/TC 338 for Menstrual products[12]. Globally, India is also developing quality and safety standards for menstrual cups and reusable cloth sanitary pads (Chemical Watch, 2020).

Formerly, there was no ecolabel established for menstrual cups. However, the Australian Government, in 2018, developed a specific Standard where the product is defined as follows: '*Menstrual cup means a product made from permissible raw materials that is inserted into the vagina and used to collect or capture menstrual discharge*' (Therapeutic Goods, 2018). Permissible raw materials is understood to refer to '*those materials which are suitable for the intended purpose of the menstrual cup which must not contain ingredients in sufficient concentration to cause a toxic or irritant reaction when used as directed*'.

In 2020, UNFPA, UNICEF and UNHCR[13] prepared the very first technical specifications for three menstrual hygiene management products, i.e. reusable menstrual cups, reusable menstrual pads, and disposable menstrual pads. The specifications were developed following a market survey and analysis of the information collected from manufacturers, collected by UNFPA and UNICEF. The specifications developed are informing a new joint tender, which both agencies are issuing for sourcing these products under global long-term agreements (UN, 2020). The technical specifications go one step further than the Australian legislation and define menstrual cups which are reusable as '*a non-absorbent bell-shaped hygienic device made of medical grade silicone, to be worn inside the vagina to collect menstrual fluid*'. It should be noted that in this case the definition refers to only one possible material to manufacture the menstrual cup.

In the United States, menstrual products are classified as medical devices and fall under the jurisdiction of the Food and Drug Administration (US FDA, 2020). The US FDA defines a menstrual cup as a receptacle placed in the vagina to collect menstrual flow, and classifies the product as Class II (out of three medical device classes[14]) (US FDA, 2020). The US FDA issued a guidance document that includes several recommendations, among them: labelling of chemical content and characteristics of technical performance of menstrual cups. Nevertheless, some important aspects to assess product safety are not addressed, e.g. standard testing methods for chemical components (Klinter, 2021). Some European menstrual cup manufacturers (FDA report, 2021) who wish to sell their products in the US have to demonstrate compliance with the US FDA recommendations. Menstrual cups are exempt from premarket notification requirements but the producers should prove that the device to be marketed is safe, effective and meets the necessary requirements to be legally marketed even without premarket approval (US FDA Premarket Notification System). Menstrual cup manufacturers are also required to report any serious adverse effects to the Manufacturer and User Facility Device Experience (US FDA MAUDE system). It is important to highlight that some menstrual cups available on the European market are advertised as being made of 'FDA approved' silicone. This might be misleading, given that the US FDA does not check or approve silicones but sets standards for silicones approval to be used in medical products, but without a specific approval of any individual final product. Moreover, menstrual cups are not FDA approved, but rather FDA registered. Only class III (what the government considers high risk) medical devices can be FDA approved.

In Europe, in view of the absence of specific harmonised legislation, menstrual cups fall under the provisions of the General Product Safety Directive (2001/95/EC), which requires the producers to ensure that products placed on the EU market are safe. Hence, it is the responsibility of each Member State to enforce the implementation of that Directive at national level and ensure that economic operators comply with their obligations. Member States may take measures preventing, restricting or imposing specific conditions on the

[12] ISO/TC 338 Menstrual products https://www.iso.org/committee/8933440.html

[13] UNFPA (United Nations Population Fund) is the United Nations sexual and reproductive health agency.

UNICEF (United Nationals International Children Emergency Fund) protects children's lives and defends their rights from early childhood through adolescence.

UNHCR (United Nations Refugee Agency) protects the rights of refugees, forcibly displaced communities and stateless people.

[14] Classes "based on the level of control necessary to assure the safety and effectiveness of the device".

marketing and use of such products, where appropriate (European Parliament, 2019). Additionally, contrary to the US case, menstrual cups are not considered medical devices and do not fall under the Medical Device Regulation (Regulation (EU) 2017/745), according to the definition given in Article 2 of that Regulation. As a result, they are not required to be manufactured from medical-grade materials.

In fact, it is common to see menstrual cups made of silicones in compliance with the positive list of Food Contact Regulation silicones. All food contact articles sold in Europe must comply with the European Food Contact Materials Regulation (Regulation 1935/2004/EC)[15]. There are countries such as Germany and France, where, besides this regulation, national regulations for silicones intended for food-contact are in place. As an example, silicone products sold in Germany must meet 'LFGB' (Lebensmittel-, Bedarfsgegenstände-und Futtermittelgesetzbuch, or 'Foods, Consumer Goods and Feedstuffs Code') testing regulations. LFGB is the German national implementation of Regulation 1935/2004/EC which only applies in Germany to silicones intended for food-contact.

2.3.2 Policy framework

The new EU Forest Strategy for 2030

The new EU Forest Strategy (COM/2021/572) sets a vision and concrete actions to improve the quantity and quality of EU forests and strengthen their protection, restoration and resilience. The strategy aims to enlarge the EU's forests to combat climate change, reverse biodiversity loss and ensure resilient and multifunctional forest ecosystems by, among other things, ensuring forest restoration and reinforced sustainable forest management for climate adaptation and forest resilience. This is particularly relevant for the EU Ecolabel criteria for Absorbent Hygiene Products addressing fibres, as forest management schemes play an important role in certifying the sustainability sourcing of the cotton and pulp used in these types of products.

Linked to this, guidelines on closer-to-nature forestry are being developed by the Commission and will feed into the work on indicators and new thresholds for sustainable forest management that will be undertaken in close partnership and cooperation with Member States through the updated EU forest governance framework. Based on these guidelines developed with Member States, the Commission will also develop a "closer-to-nature" voluntary certification scheme, so that the most biodiversity-friendly management practices could benefit from an EU quality label.

The Circular Economy Package

The Circular Economy Package includes revised legislative proposals on waste to stimulate Europe's transition towards a circular economy. The Circular Economy Package consists of an EU Action Plan for the Circular Economy that establishes a concrete and ambitious programme of action, with measures covering the whole cycle: from production and consumption to waste management and the market for secondary raw materials. The proposed actions will contribute to 'closing the loop' of product life cycles through greater recycling and reuse, and bring benefits for both the environment and the economy.

The revised legislative proposals on waste set clear targets for reduction of waste and establish an ambitious and credible long-term path for waste management and recycling. Key elements of the revised waste proposal include:

- a common EU target for recycling 65% of municipal waste by 2030;
- a common EU target for recycling 75% of packaging waste by 2030;
- a binding landfill target to reduce landfill to a maximum of 10% of all waste by 2030;
- a ban on landfilling of separately collected waste;
- promotion of economic instruments to discourage landfilling;
- simplified and improved definitions and harmonised calculation methods for recycling rates throughout the EU;

[15] 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. OJ L 338, 13.11.2004, p. 4–17, https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32004R1935

— concrete measures to promote reuse and stimulate industrial symbiosis - turning one industry's by-product into another industry's raw material;

— economic incentives for producers to put greener products on the market and support recovery and recycling schemes (e.g. for packaging, batteries, electric and electronic equipment, vehicles).

2.3.3 Environmental schemes of relevance for Absorbent Hygiene Products

The International Organization for Standardisation (ISO) has identified three broad types of voluntary labels, with Eco-labelling fitting under the Type I designation:

- Type I: voluntary, multiple-criteria-based, third-party programme that awards a licence that authorises the use of environmental labels on products indicating overall environmental preference for a product within a particular product category based on life-cycle considerations. ISO 14024 lists the guiding principles for Type I Ecolabels.
- Type II: self-declared environmental claim, i.e. environmental claim that is made, without independent third-party certification, by manufacturers, importers, distributors, retailers or anyone else likely to benefit from such a claim, in line with ISO 14021.
- Type III: voluntary programmes that provide the quantified environmental data of a product, under pre-set categories of parameters set by a qualified third party and based on life-cycle assessment, and verified by that or another qualified third party in line with ISO 14025.

There are a number of ISO 14024 type I ecolabels that address absorbent hygiene products, such as the Nordic Swan, Blue Angel, and others.

The scopes and definitions that have been identified as closely related to the EU Ecolabel AHP product group under revision are summarised in **Table 2**, based on extensive research into the market penetration of the aforementioned schemes. It should be noted that although many Ecolabels address some of the AHPs included in the EU Ecolabel, their full scope and materials differ from those of the EU Ecolabel scope.

Table 2. ISO 14024 type I ecolabels with specific criteria covering one or more absorbent hygiene product or reusable alternative

PROGRAMME NAME	LOGO	ORIGIN	DATE OF ESTABLISHMENT / LATEST REVISION (16)
EU Ecolabel		EU	2008/2014
Nordic Swan		Denmark, Norway, Sweden, Iceland and Finland	1989/2021
Blue Angel		Germany	1978/2021
Österreichisches Umweltzeichen		Austria	1990/2020
GECA (Good Environmental Choice Australia)		Australia	2000/2019
Eco Mark		Japan	1989/2015
Green Mark		Taiwan	1992/2011
Korea Eco-Label		Korea	1992/2017
China Environmental Labelling		China	1994/2019

Source: JRC.

Moreover, there are several initiatives that have been identified as relevant to the product group. They usually address sustainability aspects of the component materials of the final product and even the source of the energy used to manufacture the product (for more details please see **Table 3**).

[16] The year of *last revision* refers to the Ecolabel criteria of a given absorbent hygiene product group. Note that it may also refer to Ecolabel criteria of reusable absorbent hygiene products.

Table 3. Main environmental labels and initiatives that certify materials used in the final Absorbent Hygiene Products

PROGRAMME NAME	LOGO	ORIGIN	Material
SOIL ASSOCIATION ORGANIC		UK	Cotton
OCS 100 - Organic Content Standard		France	Organic materials
VEGANOK Company ID 0104		Italy	Entire product - Ethical Vegan Regulations
Vegan Approved		UK	No animal testing involved in the production of the product
Eco-cert		France	Organic fibres
Global Organic Textile Standard - GOTS		Germany, Japan, USA and the UK	Organic fibres
TUV Austria		Austria	Material of biobased origin
PEFC - Programme for the Endorsement of Forest Certification		Switzerland	Pulp
FSC- Forest Stewardship Council		Germany	Pulp
Naturemade Star		Switzerland	Renewable and green-sourced energy
The CFPA TCF/PCF Certification Marks		USA	Chlorine-free product
Ökotex 100		Switzerland	Components of an article are tested for harmful substances
BioPreferred® Program		USA	Biobased content

PROGRAMME NAME	LOGO	ORIGIN	Material
MADE SAFE		USA	Certification for non-toxic products
Cradle to Cradle		USA	Product's material health, material reuse, renewable energy and carbon management, water stewardship, and social fairness
Seal of Cotton		USA	Products made of cotton

Source: JRC.

A brief description of the ISO 14024 type I ecolabels is given below:

— Nordic Swan

The Nordic Swan is the official Ecolabel of the Nordic countries: Sweden, Iceland, Denmark, Finland and Norway. The Nordic Swan criteria document for Sanitary Products (Version 6.8) includes the following products: breast pads, children's diapers, incontinence care products, (panty liners, formed diapers and diapers with tape strips), sanitary towels (pads and panty liners), tampons, cotton buds, cotton pads, cotton wool, sauna underlays, bibs, plasters, compresses, mattress covers/protectors, draw sheets, bed linen, wash cloths (except paper cloths), surgical gowns, patient gowns/patient covers, surgical masks and caps. Relevant disposable products in addition to those specified above may be included in the product group upon request if they are viewed as sanitary products.

The Nordic Swan background document for Sanitary Products indicates the possibility to ecolabel reusable diapers under the criteria for textiles.

— Blue Angel

The German Ecolabel, Blue Angel, is the oldest ecolabel in the world and was introduced in 1978. The latest edition for Absorbent Hygiene Products is DE-UZ 208 from January 2021. The scope for disposable hygiene products covers nappies (e.g. disposable nappies, nappy liners, swim nappies and pants), incontinence products (e.g. incontinence pads, disposable pants, incontinence slips and anal tampons) and feminine hygiene products (panty liners, sanitary towels, tampons and nursing pads).

— Österreichisches Umweltzeichen

The Austrian Ecolabel is primarily aimed at consumers but also at manufacturers and public procurement. The label provides consumers with guidance in order to choose products or services with the least harmful impact on the environment or health. Reusable hygiene products can be awarded the Austrian Ecolabel for textiles. However, at the moment there are no specific criteria for this product category or for disposable absorbent hygiene products.

— GECA (Good Environmental Choice Australia)

The GECA Ecolabel addresses multiple environmental attributes such as toxicity, air quality, energy use, recyclability, VOCs, carcinogens, reducing water consumption, protecting waterways, use of sustainable materials and minimising material usage. The Ecolabel considers a life-cycle approach, considering the requirements from raw material extraction to disposal of the product. The last revision for personal care products was done during 2013, and the new criteria were the result of the independent research work of manufacturers and other industry experts.

GECA has released a Sanitary Products standard which is a version of the Nordic Swan Ecolabel's standard that has been modified to be relevant to the Australian market.

Products included in the scope of this standard are: breast pads, children's diapers, incontinence care products, (panty liners, formed diapers and diapers with tape strips), sanitary towels (pads and panty liners), tampons, cotton buds, cotton pads, cotton wool, sauna underlays, bibs, plasters, compresses, mattress covers/protectors, draw sheets, bed linen, washcloths (except paper cloths), surgical gowns, patient gowns/patient covers, surgical masks and caps.

— Eco Mark

In 1989, the Japanese Environment Association (JEA) developed the Eco Mark in collaboration with the Ministry of the Environment. Together with Germany, the Scandinavian countries and Canada, Japan is among the first countries to introduce ecolabelling schemes as an instrument of politics. A special feature of the Japanese ecolabelling scheme is the fact that the scheme is not implemented and managed by a national body but by a Japanese environmental association.

The Eco Mark Product Category No.104 "Household Textile Products" includes reusable baby diapers made out of textiles in the scope. The Japanese Ecolabel does not include disposable absorbent hygiene products at the moment.

— Green Mark

The Green Mark is administered by the Environmental Protection Administrations of R.O.C (Taiwan). Product categories include cloth diapers and unbleached towels. Criteria for cloth diapers are defined as follows: *The product shall not contain fluorescent whitener, formaldehyde, or other hazardous chemicals. The product shall last for at least 150 times of use to bear a label reading "reusable diaper". The diaper shall contain not less than 50 % cotton*.

— Korea Eco-Label

The Korea Eco-Label was launched into the market by the government of the Republic of Korea in 1992. Administration and organisation are in the hands of the Korea Environmental Labelling Association (KELA).

The Korea Eco-Label has criteria standards for disposable baby diapers.

— China Environmental Labelling (CEL)

In 2003, CEL, under the State Environmental Protection Administration of China, was established to take charge of certification criteria establishment and certification work.

The Chinese Environmental Labelling has technical requirements for the environmental labelling of Absorbent Hygiene Products. China, Japan and Korea aim to identify core indicators for common criteria for "Paper Diapers" in the coming years.

Other certification schemes that can be found on packaging of Absorbent Hygiene Products which certify materials included in the article:

— Soil Association Certification

Soil Association is a not-for-profit business which certifies organic products. It also offers a huge range of organic and sustainable certification schemes across food, farming, catering, health and beauty, textiles and forestry.

Soil Association Certification was launched in 1973. The Soil Association Health and Beauty standard exists for products that are not classed as 'cosmetics'. This includes any household cleaning products, intimate health products and products that fall under the medical category.

— OCS 100 - Organic Content Standard

The Organic Content Standard (OCS) is an international, voluntary standard that sets requirements for third-party certification of organic input and chain of custody.

OCS 100 covers the processing, manufacturing, packaging, labelling, trading and distribution of a product that contains at least 95% certified 'organic' materials.

The OCS was the first standard developed by the global non-profit organisation Textile Exchange that works closely with all sectors of the textile supply chain.

— Cotton Incorporated

Introduced in 1973, the Seal of Cotton trademark was created to provide a visual reference for consumers to identify products made of cotton. Companies that wish to get the trademark just need to send a one-page Product Information Sheet as well as a sample of the product to be checked by Cotton Incorporated. No specific criteria have been found.

— ECOCERT

ECOCERT is an organic certification organisation created in France in 1991. It is based in Europe but conducts inspections in over 80 countries, making it one of the largest organic certification organisations in the world. ECOCERT organic certification has been found mainly on feminine care pad packaging.

— TUV Austria, OK Biobased

This certification deals with the product's origin. If the product has a biobased origin, then the logo uses stars to indicate the amount of biobased content in the product. Four stars indicate that more than 80% of the material is of biobased origin. One star indicates that less than 20% of the raw material comes from renewable sources.

— PEFC - Programme for the Endorsement of Forest Certification

This certification provides a mechanism to promote the sustainable management of forests while ensuring that forest-derived products that reach the market have been sourced from sustainably managed forests. This certification sets requirements that companies must comply with to achieve PEFC chain of custody certification, but also the specific steps stakeholders must take as they develop their national forest certification system.

— FSC - Forest Stewardship Council

FSC also certifies the sustainable management of forests and the chain of custody to provide confirmation about products being environmentally and socially responsibly sourced before their access to market.

— The Global Organic Textile Standard (GOTS)

GOTS is the worldwide leading textile processing standard for organic fibres, including ecological and social criteria, backed up by independent certification of the entire textile supply chain. GOTS certified final products may include fibre products, yarns, fabrics, clothes, home textiles, mattresses, personal hygiene products, as well as food-contact textiles and more.

A textile product carrying the GOTS label must contain a minimum of 70% certified organic fibres and a product labelled 'organic' must contain a minimum of 95% certified organic fibres.

It should be noted that there is no organic standard for feminine care products, but in the case of products made of a natural textile, they are considered to fall into the organic textile category.

— VEGANOK Company ID 0104

VEGANOK is the first and only standard for Ethical Vegan Products created in Italy. The company that decides to self-declare its vegan services and products through the VEGANOK standard does so in compliance with the European regulation UNI EN ISO 14021, Type II environmental labelling. The labelling of the product shall meet the requirements as described in the current Laws and Regulations. The VEGANOK Ethical Regulations shall be considered as constantly evolving guidelines, subject to improvements and always available for public consultation.

— Naturemade

Naturemade is a Swiss label for energy from 100% renewable sources. Certification is available at two levels, i.e. Naturemade star and Naturemade basic. The quality label Naturemade star denotes 100% eco-energy while naturemade basic is 100% renewable energy. They are awarded for plants producing renewable energy (electricity, heat/cooling and biomethane); certification is also available for the supply of energy from these plants to end consumers. The Naturemade guidelines must be followed for the Association for Environmentally Sound Energy (VUE) to grant certification. This certification has only been found in one brand of disposable baby diapers.

— TCF and PCF

The TCF (Totally Chlorine Free) and PCF (Processed Chlorine Free) certification schemes are proposed by the Chlorine Free Products Association (CFPA). They certify that a product has been manufactured and bleached without any use of chlorine.

— Ökotex 100

STANDARD 100 by OEKO-TEX® is one of the world's best-known labels which tests for harmful substances. In the test they take into account numerous regulated and non-regulated substances, which may be harmful to human health. In many cases, the limit values for the STANDARD 100 go beyond national and international requirements. The criteria catalogue is updated at least once a year and expanded with new scientific knowledge or statutory requirements.

— MADE SAFE

MADE SAFE is a programme of Nontoxic Certified, a non-profit organisation and the Americas' first comprehensive human–health- and ecosystem-focused certification for non-toxic products across store aisles, from baby to personal care to household. The MADE SAFE™ (Made With Safe Ingredients) approach screens out known toxicants and does not permit known behavioural toxins, carcinogens, developmental toxins, endocrine disruptors, fire retardants, GMOs, heavy metals, neurotoxins, pesticides, reproductive toxins, toxic solvents or harmful VOCs in products. The standard also scientifically screens ingredients that have little to no publicly available data and evaluates ingredients of concern for bioaccumulation, persistence, and general and aquatic toxicity.

— Cradle to Cradle

The Cradle to Cradle Certified Products Standard evaluates products across five categories of human and environmental health and is administered by the Cradle to Cradle Products Innovation Institute, a non-profit organisation. To receive certification, products are assessed across: material health, material reuse, renewable energy and carbon management, water stewardship, and social fairness. A product is assigned an achievement level (Bronze, Silver, Gold, Platinum) for each category. A product's lowest category achievement also represents its overall certification level. At the moment, there are disposable baby diapers in the Cradle to Cradle Certified Products Registry.

2.4 Product categorisation

In this chapter, a revision of the different classification of absorbent hygiene products according to different sources is presented. A proposal for a categorization of the different absorbent hygiene products to be included in this criteria revision is proposed in the last section of this chapter.

2.4.1 PRODCOM data

The PRODCOM (Production Communautaire) statistics provide a picture of the EU level of development in industrial production for different products or industries, and allow the comparison between EU countries (Eurostat METADATA PROD COM List, 2019).

According to the METADATA PRODCOM List 2019, Absorbent Hygiene Products fall under the C17.22 NACE class: Manufacture of household and sanitary goods and of toilet requisites. More specifically, they are classified under the CPA code (European Union Classification of Products by Activity) 17.22.12*: Sanitary towels and tampons, napkins and napkin liners for babies and similar sanitary articles and articles of apparel and clothing accessories, of paper pulp, paper, cellulose wadding or webs of cellulose fibres*. **Table 4** summarises relevant PRODCOM classification codes; those that are directly applicable to disposable baby diapers and feminine care products are marked in **bold**.

Table 4. List of codes and labels included in PRODCOM classification regarding Absorbent Hygiene Products. Those that are directly applicable to disposable baby diapers and feminine care products are marked **in bold**

PRODCOM	Description
17.22.12.10	Sanitary towels and tampons, napkins and napkin liners for babies and similar sanitary articles, of wadding
17.22.12.20	**Sanitary towels, tampons and similar articles of paper pulp paper, cellulose wadding or webs of cellulose fibres**
17.22.12.30	**Napkins and napkin liners for babies and similar sanitary articles of paper pulp, paper, cellulose wadding or webs of cellulose fibres, (excluding toilet paper, sanitary towels, tampons and similar articles)**
17.22.12.40	Wadding; other articles of wadding
17.22.12.50	Articles of apparel and clothing accessories of paper pulp; paper; cellulose wadding or webs of cellulose fibres (excluding handkerchiefs, headgear)
17.22.12.60	**Sanitary towels (pads), tampons and similar articles, of other textile materials (excl. of wadding of textile materials)**
17.22.12.70	**Napkins and napkin liners for babies, of other textile materials (excl. of wadding of textile materials)**
17.22.12.90	Household, sanitary or hospital articles of paper, etc.

Source: METADATA PRODCOM List, 2019.

In Table 5, the comparison between PRODCOM and CN codes (EU, 2020) for the EU is included, when possible. The CN code 961900 corresponds to "*Sanitary towels (pads) and tampons, napkins and napkin liners for babies, and similar articles, of any material*", while subheadings are also defined in **Table 5**.

Table 5. PRODCOM description and CN codes regarding Absorbent Hygiene Products

PRODCOM	Description	CN code
17.22.12.10	Sanitary towels and tampons, napkins and napkin liners for babies and similar sanitary articles, of wadding	96190030 This subheading includes sanitary towels and tampons, napkins and napkin liners for babies, and similar sanitary articles, consisting of wadding, whether or not with knitted or loosely woven open-work covering.
17.22.12.20	Sanitary towels, tampons and similar articles of paper pulp paper, cellulose wadding or webs of cellulose fibres	Sanitary towels (pads) 96190071 Tampons 96190075 Other 96190079 This subheading includes panty shields.
17.22.12.30	Napkins and napkin liners for babies and similar sanitary articles of paper pulp, paper, cellulose wadding or webs of cellulose fibres, (excluding toilet paper, sanitary towels, tampons and similar articles)	Napkins and napkin liners for babies 96190081 Other (for example, incontinence care articles) 96190089

PRODCOM	Description	CN code
17.22.12.60	Sanitary towels (pads), tampons and similar articles, of other textile materials (excl. of wadding of textile materials)	96190040 Includes sanitary towels (pads), tampons and similar articles
17.22.12.70	Napkins and napkin liners for babies, of other textile materials (excl. of wadding of textile materials)	Napkins and napkin liners for babies, and similar articles 96190050

Source: METADATA PRODCOM List, 2019 and CN.

2.4.2 Euromonitor data

Euromonitor is a market data analyst and provider with a database that includes information on Absorbent Hygiene Products. The Euromonitor database has its own product classifications and definitions. Accordingly, the product category of potential interest for the ongoing revision is classified as *Retail Hygiene*, and further divided into the following subcategories:

- Retail Adult Incontinence: includes a variety of protective products for different levels of bladder or bowel adult incontinence. Products with different levels of absorbency are covered, including pads, pants/protective underwear, briefs, undergarments and pant/pad systems.
- Disposable Pants: includes pant format diaper as well as products designed for toilet training of babies or small children. Disposable pants are usually thinner than diapers, but resemble diapers in their absorbency and are similar to normal underwear in design and the way they are worn. Included are also products designed for children with bed-wetting issues.
- Nappies/Diapers: disposable baby nappies/diapers - segmentation within the market has been created by the development of niche markets, for example the ultra-slim, super-absorbent nappy, and the boy, girl and unisex nappies. This sector only includes disposable nappies, not those that are washed and reused.
- Panty liners: external sanitary protection designed for light flow, may be used in conjunction with a tampon, often promoted as offering protection and “freshness” throughout the whole month, having minimal absorbency.
- Tampons: sanitary protection, used internally, either with or without applicator (“digital”).
- Towels: sanitary protection used externally – includes press-on and looped towels.

2.4.3 EDANA categorisation

EDANA is the Industry association for non-wovens and related industries. EDANA[17]’s member companies are AHP manufacturers and suppliers, covering the entire supply chain of the AHP manufacturing process, including testing and development facilities. More than 300 member companies with headquarters in over 40 different countries who operate worldwide are represented.

According to the EDANA definition, Absorbent Hygiene Products are single-use products made from non-wovens and other raw materials. The association divides the product group into two categories (EDANA, 2018):

- Diapers, for baby and adult incontinence (also called ‘nappies’).

[17] EDANA is the Industry Association for nonwovens and related industries. EDANA’s member companies are the AHP manufacturers and their suppliers, covering the entire supply chain of the AHP manufacturing process, including testing and development facilities (https://www.edana.org/).

— Absorbent feminine hygiene products such as menstrual tampons, napkins, pads and panty liners (sometimes collectively referred to as ‘femcare’, ‘fempro’, ‘feminine hygiene’ or ‘sanitary protection’ products).

2.4.4 Reusable alternatives for Absorbent Hygiene Products

The current product group’s scope focuses on products with high absorptive capacities excluding reusable products. However, a preliminary analysis was performed prior to the start of the revision process in order to identify the key environmental areas of concern associated with AHPs, in comparison to the possible reusable alternatives available in the European market. Additionally, a general overview of the market situation as regards AHPs and some reusable alternatives was developed.

Materials used in disposable AHPs include cotton, cellulose pulps and fibres and plastics and polymers while reusable alternatives include a variety of materials in their composition as explained below.

Multiple-use alternatives to the articles addressed by the current AHP EU Ecolabel scope have been identified:

— **Reusable menstrual cups** are usually made of medical-grade silicone, rubber, latex, or elastomer and can last up to 10 years. See **Figure 2**a.

— **Cloth menstrual pads** are cloth pads that, like disposable pads, are placed on the underwear area in closest contact with the skin to prevent menstrual fluid from leaking onto clothes. These reusable alternatives can be washed, dried and then reused. Generally, they are made from layers of absorbent fabrics (such as cotton or hemp). The cloth pads can last between 1 and 5 years. See **Figure 2**b.

— **Cloth baby diapers** are made from natural fibres, man-made materials, or a combination of both. They are often made from industrial cotton. They are washable and reusable. See **Figure 2**c.

— **Reusable breast pads** or reusable nursing pads absorb breast milk that runs out. They protect clothing from damp stains and keep the skin dry and clean. Reusable nursing pads found in the market nowadays are made of natural fibres such as wool, silicone or plastic. They are washable and reusable. See **Figure 2**d.

— **Period underwear** is usually fabricated using combined tissues. They typically have layers of cotton and waterproof material. The area in direct contact with the skin is usually made of cotton. Underneath, there is the technical tissue, which is absorbent, waterproof, antibacterial and breathable. The external layer works as a barrier to possible leaks and can be made of elastane or nylon. They are washable and reusable and can last up to 3 years. See **Figure 2**e.

Figure 2. Reusable hygiene products

Source: images #277059632, #336786018, #229278127, and #239511058 from stock.adobe.com.

Table 6. List of absorbent hygiene products addressed by the EU Ecolabel criteria (2014/763/EU) and their reusable alternatives

EU Ecolabel scope – disposable	Reusable alternatives
Disposable Baby Diapers	Cloth Baby Diapers
Disposable Feminine/Menstrual Pads	Menstrual Cup Cloth Pads Period Underwear
Tampons	Menstrual Cup Period Underwear
Disposable Breast Pads	Reusable Breast Pads

Source: JRC.

2.4.5 Proposal for Absorbent Hygiene Products categorisation for this EU Ecolabel

There is no standardised definition of the Absorbent Hygiene Product group. As it has been shown in previous sections, different sources classify products differently and some categories can include products of different material composition and functionality (end-use function).

Products included in the same category can differ in the following aspects:

— Composition: the materials used and their weight differ depending on the AHP, for example elastics are only used in the case of baby diapers. Additionally, some ingredients are intentionally used in certain products. This is the case of lotions which are included in some baby diapers.

— Intended end-use: Absorbent Hygiene Product (for menstrual protection, for baby incontinence care, etc.).

— Packaging: Absorbent Hygiene Products can be found in different packaging: individually wrapped in thin plastic film and transferred afterwards to a secondary box, in the case of tampons.

The following considerations have been taken into account in order to propose a harmonised list of product categories to be included in this revision:

a. All products included in the current scope of the EU Ecolabel for Absorbent Hygiene Products as well as their reusable alternatives are considered.

b. Feminine hygiene products have been grouped with feminine care products as they have the same function of absorption of body fluids.

c. Reusable hygiene products made out of textiles as well as reusable menstrual cups are included in the preliminary categorisation; however, their inclusion in the scope will be considered depending on the degree of adaptability of the current criteria.

The categorisation proposed to be used in this revision is presented in **Table 7**, where the categories already covered by the current product group scope appear **bold green**.

Table 7. Proposed categorisation to be used during the revision

PROPOSED CATEGORIES			
Adult incontinence care products		Disposable (single-use) incontinence products	Products intended to be used by adults in order to keep body fluids when uncontrolled bladder or bowel movements and aimed to make their everyday lives easier. Although the most common products are pads and diapers, other products include disposable underwear and incontinence slips or tampons.
Baby diapers or nappies		**Disposable (single-use) baby diapers or nappies**	Products to be used by babies to keep their body fluids and made of disposable materials as cellulose and polymers, thus being a single-use product.
		Reusable baby diapers or nappies (cloth diapers or cloth nappies)	Products to be used by babies to keep their body fluids and made of cloth and other fibres which can be washed for its use for a certain number of years.
Feminine sanitary protection	Sanitary Pads or Towels	**Disposable (single-use) sanitary pads or towels**	Products used by women when menstruating to absorb fluids from the body. Usually they are placed on the underwear, are made of cellulose and polymers and dispose after use.
		Reusable sanitary pads or towels (cloth pads or towels)	Products used by women when menstruating to absorb fluids from the body. Usually they are placed on the underwear, are made of a variety of fibres and can be washed and reused.
	Panty Liners	**Disposable (single-use) panty liners**	Products used by women in a daily-basis to absorb fluids from the body. They are thinner than pads. Usually they are placed on the underwear, are made of cellulose and polymers and dispose after use.
		Reusable panty liners (cloth panty liners)	Products used by women in a daily-basis to absorb fluids from the body. They are thinner than pads. Usually they are placed on the underwear, are made of a variety of fibres and can be washed and reused.
	Tampons	**Disposable (single-use) tampons**	Products made of natural fibres as cotton which are placed inside the vagina to absorb menstrual fluids and blood. They have a bullet shape, can be used with or without applicator and are disposable.
	Menstrual Cups	Disposable (single-use) menstrual cups	Flexible cups or barriers worn inside the vagina during menstruation to collect menstrual fluid rather than absorbing it. They are usually made from different disposable polymers.
		Reusable menstrual cups	Flexible cups or barriers worn inside the vagina during menstruation to collect menstrual fluid rather than absorbing it. They are usually made from different stable and reusable materials which allows them to be washed and reused for up to 10 years.
	Nursing Pads (breast pads)	**Disposable (single-use) nursing pads (or breast pads)**	Pads used to absorb and keep fluids away from the skin when breastfeeding. Disposable nursing pads are usually made of cellulose materials.
		Reusable nursing pads or breast pads (cloth nursing pads or breast pads)	Pads used to absorb and keep fluids away from the skin when breastfeeding. Reusable nursery pads can be made of several natural fibres.

Source: JRC.

2.5 Other relevant information

This Preliminary Report includes an exhaustive market analysis (Task 2) and a technical analysis, which provides specific information on environmental, health and technical issues related to absorbent hygiene products (Task 3).

In this section, aspects taken into account while evaluating potential extension of the scope are presented:

- General data about European AHP market.
- Information about the environmental impacts of different Absorbent Hygiene Products.

2.5.1 Preliminary market assessment of AHPs

The 2019 Worldwide Outlook for the Nonwovens Industry Report forecast strong market demand for non-woven materials over the next 5 years. Across the non-woven end-use segments, absorbent hygiene applications recorded the highest incremental volume, with 1.3 million tonnes (EDANA, 2019).

In 2020, the main market segments in term of volume for non-woven roll goods was hygiene (27.9%) (EDANA, 2020). The main end use for non-wovens remains the hygiene market with a 28% share of deliveries, amounting to 857 940 tonnes, a growth of 9.6% in 2020 compared to 792 620 tonnes, and a growth of 1.5% achieved in the previous year (EDANA, 2021).

Two main sources of information have been selected to present a brief overview of the market of Absorbent Hygiene Products: Euromonitor International and PRODCOM data.

Euromonitor International does not currently track sales of reusable hygiene products as the retail sales across the EU markets are considered negligible, with a less than 1% market share. However, global data for reusable hygiene product alternatives made out of textiles as well as data for reusable menstrual cups were collected from published information contained in Market Reports.

Additionally, an estimation of EU market data for reusable alternatives made out of textiles has been taken from PRODCOM. Given the level of aggregation in the PRODCOM categories, the reusable products made out of textiles are assumed to be comprised in the categories 17.22.12.10, 17.22.12.60 and 17.22.12.70 (Table 4)[18].

The menstrual cups market in Europe is anticipated to reach USD 185.19 million by 2027 from USD 124.43 million in 2019. The market is projected to grow at a CAGR of 5.2% during 2020–2027 (Report Linker, 2020). If these values are compared with the disposable menstrual products market value from 2019 (USD 3.1 billion), the menstrual cup market seems to represent 4% of the market and it is set to keep increasing.

Table 8 summarises the EU market data from PRODCOM where AHPs are included. From this list, the PRODCOM categories where EU market data for reusable AHPs would be included are shown in **bold**. These are the categories 17.22.12.10, 17.22.12.60 and 17.22.12.70. The total annual sales volume for these three categories accounts for 3.5% or EUR 287.4 million of the overall sales volume in 2019 in the EU-28.

[18] 17.22.12.10 Sanitary towels and tampons, napkins and napkin liners for babies and similar sanitary articles, of wadding

17.22.12.60 Sanitary towels (pads), tampons and similar articles, of other textile materials (excl. of wadding of textile materials)

17.22.12.70 Napkins and napkin liners for babies, of other textile materials (excl. of wadding of textile materials)

Table 8. Estimation of EU market data for reusable alternatives made out of textiles from PRODCOM (2019)

PRODCOM	Description	Annual sales volume 2019 in MEUR (EU-28)	% of overall sales volume (EU-28)
17.22.12.10	**Sanitary towels and tampons, napkins and napkin liners for babies and similar sanitary articles, of wadding**	**281**	**3.43**
17.22.12.20	Sanitary towels, tampons and similar articles of paper pulp paper, cellulose wadding or webs of cellulose fibres	1 503	18.3
17.22.12.30	Napkins and napkin liners for babies and similar sanitary articles of paper pulp, paper, cellulose wadding or webs of cellulose fibres, (excluding toilet paper, sanitary towels, tampons and similar articles)	4 880	59.6
17.22.12.40	Wadding; other articles of wadding	627	7.65
17.22.12.50	Articles of apparel and clothing accessories of paper pulp; paper; cellulose wadding or webs of cellulose fibres (excluding handkerchiefs, headgear)	40	0.5
17.22.12.60	**Sanitary towels (pads), tampons and similar articles, of other textile materials (excl. of wadding of textile materials)**	**2.8**	**0.03**
17.22.12.70	**Napkins and napkin liners for babies, of other textile materials (excl. of wadding of textile materials)**	**3.6**	**0.04**
17.22.12.90	Household, sanitary or hospital articles of paper, etc.	849	10.37

Source: PRODCOM.

The total global market share for Absorbent Hygiene Products currently included in the scope was approximately EUR 37 billion in 2020 whereof the market share for feminine care products accounted for nearly EUR 17 billion and over EUR 20 billion for baby diapers (Euromonitor International, 2021).

The total EU market share for Absorbent Hygiene Products under the current scope is EUR 6 billion in the EU-27 and the UK in 2020 (EUR 3.5 billion for baby diapers and EUR 2.5 billion for feminine care products) (Euromonitor International, 2021).

No market data for reusable feminine care pads and panty liners of textile materials or for reusable breast pads has been found.

2.5.2 Preliminary review of LCA-related literature

In the Technical Analysis (Task 3) the environmental impacts of absorbent hygiene products will be analysed from a life cycle perspective. In this section a preliminary assessment of the potential environmental impact of each product is included by reviewing LCA studies available in the literature.

The LCA analysis conducted during the previous revision process highlighted that the main contributor to the environmental impacts of AHPs were attributed to material manufacturing (62-97%). In general, materials of a higher mass content in a final product contributed toward the highest shares of environmental impacts (Cordella et al., 2013).

Since all AHPs in the scope of the study were mainly composed of similar materials, a baby diaper was well suited to being a reference case. By far the main contributor to the environmental impacts of a baby diaper was attributed to materials. The End-of-Life (EoL) contributed to Eutrophication Potential, Photochemical Ozone Creation Potential and Global Warming Potential mainly because of the emissions related to waste disposal in incineration and landfill plants. For baby diapers, fluff pulp was the main contributor within each impact category. Superabsorbent polymer (SAP) and polypropylene (PP) non-woven also contributed appreciably to the results. Due to its petrochemical origin, SAP and the PP non-woven hardly influence the primary energy demand from renewable raw materials, in contrast to fluff (98% of relative contribution to the overall impacts for a baby diaper) (Cordella et al., 2013).

Waste water generated during manufacturing of disposable diaper components and of the final product has a relatively low impact on the environment when compared to air pollution because the traditional manufacturing process used (wet-laid technique associated with chemical bonding) is gradually being replaced by the air-laid technique with the use of thermal bonding (Kakonke et al., 2019).

Cordella et al. (2013) also studied feminine care products. Fluff pulp resulted to be the key material even for sanitary pads, being the main contributor in all impact categories with the exception of AP (Acidification potential). For this impact category, the siliconised release paper had a slightly higher impact than cellulose caused by the use of silicone. For GWP, besides fluff pulp, adhesives and plastic materials such as PP, PET and LDPE also contributed to comparable shares (8-13%) in the results.

Looking at the LCA results for the tampon modelled in that study, it was apparent that the environmental impacts are almost completely due to cotton content, i.e. the main component considered, and due to the presence of a plastic applicator. Cotton provided the highest contribution to all the impact categories considered in the assessment apart from primary energy demand from non-renewable resources. The applicator had a strong influence on GWP, POCP and primary energy demand from non-renewable resources due to its energy-intensive production and its crude oil origin. The PP top layer and string had a negligible influence on the results because of their low masses (Cordella et al., 2013).

For breast pads, results looked similar to sanitary pads: fluff pulp was the main contributor to all impact categories. SAP showed significant shares in GWP and primary energy demand from non-renewable raw materials due to its energy-intensive production. The siliconised paper was (as for sanitary pads) driving ADP due to the production of the silicon resin (Cordella et al., 2013).

A more detailed review of the latest LCA studies that have been published since the last EU Ecolabel revision will be addressed in Section 4 of this report (Part of Task 3: technical analysis). Most of these studies refer to the environmental impacts of each type of disposable absorbent hygiene product (usually pads, tampons or baby diapers) while other scientific papers encompass a comparison between the disposable and their reusable alternatives.

However, a limited number of these papers analyse the whole life cycle of the AHP under the EU Ecolabel scope. As a result, the literature analysed is only sufficient to identify qualitatively the environmental hotspots of disposable pads, tampons and baby diapers but not of breast pads. Additional technical studies would be needed to clearly support the advantage of reusable alternatives.

Most scientific papers conclude that the main impact of the disposable AHP is attributed to the production and EoL phases of the product's life cycle (Cordella et al., 2015; Hoffman et al., 2020).

For the disposable AHPs, there are opportunities for the EU Ecolabel to set up criteria to increase the amount of materials that are biodegradable beyond the organic cotton. Efforts should also be directed towards a higher consumer awareness on the correct product use and disposal. Despite the organic content that the product may have, if the disposal is not correct, the biodegradability potential will be reduced considerably, resulting in it having the same EoL impacts as its non-organic counterparts. More LCA studies are needed in order to draw robust conclusions on their potential environmental advantage over the reusable products.

By contrast, the reusable menstrual cup has been reported to have substantially lower environmental impacts than the single-use menstrual products. This was shown to be the case across all impact categories and regardless of the material from which the menstrual cup was produced (Weir, 2015; Leroy et al., 2016; Hait and Powers, 2019).

Other reusable AHPs such as period underwear and cloth baby diapers also have an important environmental impact due to the electricity consumption during the production and use phase and the chemicals used during the production process. In particular, for baby diapers, a difference in the assumptions on the age of toilet-training, temperature of washing and energy efficiency of the washing machine results in differences in outcomes in different studies. Thus, based on the lack of available scientific literature, it cannot be concluded that reusable baby diapers have a lower carbon footprint than disposable ones (OVAM, 2018; UNEP, 2021).

Many of the aspects that affect environmental performance are geographically dependent, such as available feedstock for biobased materials, available power generation technology, consumer behaviour with regard to reusable alternatives and use habits, and available waste management systems and disposal practices. Menstrual products made from locally sourced materials were found to have environmental and social advantages in the local market, but these benefits did not necessarily extend to these products when exported (UNEP, 2021).

2.6 Feedback from the EU Ecolabel preliminary revision questionnaire

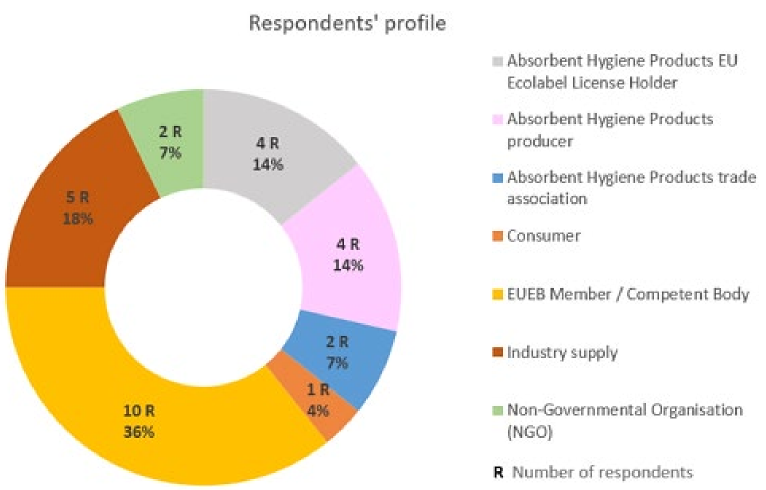
Task 1 of the revision project includes the preparation of an EU Ecolabel revision questionnaire to obtain information regarding the following aspects:

- Analysis of the validity of the current scope and definitions. Proposal of the scope extension.
- Analysis of the validity of the existing EU Ecolabel criteria.

While the present section addresses the analysis of the validity of the current scope and definitions, the analysis of the validity of the existing EU Ecolabel criteria will be presented in Section 4.5.

In total, 28 responses were received to the questionnaire. **Figure 3** summarises the overall profile of respondents:

Figure 3. Profile of the questionnaire respondents



Source: Outcomes of the preliminary questionnaire (internal document). December 2020.

The majority of respondents represent EU Ecolabelling Board (EUEB) members/Competent Bodies followed by industry supply companies who provide Absorbent Hygiene Product components and/or materials.

An overview of the involvement of the respondents in the EU Ecolabel can be observed in **Table 9** below.

Table 9. EU Ecolabel involvement of the questionnaire respondents

Involvement of questionnaire respondents in EU Ecolabel developments	Number of respondents
Been actively involved with the EU Ecolabel criteria development process for Absorbent Hygiene Products on previous occasions	16
Obtained an EU Ecolabel licence for this product group	6
In the process of applying for an EU Ecolabel licence for this product group	4
Potentially considering applying for an EU Ecolabel licence for the product group	3
None of the above	4

Source: JRC.

2.6.1.1 Analysis of the validity of the current scope and definitions

In the questionnaire responses, 57% (16) of stakeholders indicated that the current scope and definition of the product group need to be revised.

In general, stakeholders expressed that feminine care products such as 'pads /panty liners', 'tampons' or 'breast pads' and 'baby diapers' – should be maintained in the scope.

When the respondents were asked about the inclusion of incontinence products in the scope, 82% of stakeholders (23 out of 28) were in favour of including incontinence products in the scope of AHPs. More concretely, most of the respondents indicated that all products for light, moderate and heavy incontinence should be included. Additionally, some respondents highlighted the following: *Incontinence products for private as well as professional care should be included, i.e. adult diapers, panty liners and towel, liners, pads and pants. A detailed list of products should be checked further.*

39% of respondents supported the inclusion in the scope of reusable alternatives for AHPs. The reusable alternatives whose inclusion was analysed are: reusable menstrual cups, cloth baby diapers, feminine care pads, reusable breast pads. However, at the EU Ecolabelling Board (EUEB) meeting held in November 2020, some of the EUEB members stated that while reusable alternatives serve the same purpose as single-use AHPs, their material composition is different, and inclusion in the textile product group should be preferred. This would apply to reusable alternatives such as reusable feminine care pads, breast pads and baby diapers. Indeed, other Ecolabels such as the Austrian Ecolabel include reusable alternatives under their textile Ecolabel scope.

Moreover, new criteria would be needed in the case of including menstrual cups in the scope, to take into account the different material composition of menstrual cups. A respondent highlighted that reusable sanitary pads/panty liners or diapers are currently not widely used. However, market uptake could be increased if included under the EU Ecolabel scheme.

Another respondent asked for scope extension to some types of non-woven wipes and cotton pads and buds that are used for personal hygiene while another one indicated that products for bed protection could be included along with incontinence products.

Finally, four respondents indicated general reasons why reusable alternatives should be included:

- Similar components / similar production process / quite often same producers / same functionality.
- Some demand is already emerging in the market for EU Ecolabel products.
- No need for additional criteria / adaptation needed for some of them.
- In line with the EU Circular Economy objectives, alternatives that promote zero waste generation through consumption should be incentivised.

2.7 Proposal for scope and definition for this EU Ecolabel

According to the rationale behind the definition of the product scope given in the previous revision Absorbent Hygiene Products Preliminary Report (Chapter 2.2), reusable textile alternatives could not be included as they can be assessed under the EU Ecolabel criteria for textiles (Cordella et al., 2013). However, in the Policy Brief (2020) it was stated that the potential inclusion for reusable alternatives should be investigated.

Therefore, in the following sections the possibility of including reusable products (those not in bold in **Table 7** of Section 2.4.5) is analysed.

2.7.1 Methodology to assess the potential of inclusion

The selection of which reusable product categories should be included in the scope has been done considering the following relevant aspects:

- Similarity of material components, compared to products included in the existing scope (according to data provided in Sections 2.2 and 2.4).
  - High similarity
  - Medium similarity
  - Low similarity
- Inclusion in other Ecolabels and environmental schemes (according to data provided in Section 2.3.3).
  - More than 75% of the schemes include the product group
  - Between 25-75% of the schemes include the product group
  - Less than 25% of the schemes include the product group
- Stakeholder's interest in the inclusion of specific product (according to data provided in Section 2.6).
  - More than 60% of stakeholders interested in the inclusion
  - Between 40-60% of stakeholders are interested in the inclusion
  - Less than 40% of stakeholders are interested in the inclusion
- Market share of the product (according to data provided in Section 2.5.1).
  - More than 10% of the market share average for AHPs currently in scope
  - Between 3-10% of the market share for AHPs currently in scope
  - Less than 3% of the market share for AHPs currently in scope
- Environmental impacts (according to data provided in Section 2.5.2).
  - High similarity
  - Medium similarity
  - Low similarity

The scoring of the different above mentioned aspects for each product have been done considering the next equivalence:

2 points

1 point

0 points

The results of this evaluation are presented in **Table 10**. The potential for inclusion of the products have been done considering the following scale. Once the classification is completed, a total punctuation from 0 to 10 could be obtained.

Punctuation	0	1	2	3	4	5	6	7	8	9	10
Potential for inclusion	Low				Medium			High			

Table 10. Summary of the product group categories and assessment of the potentially inclusion in the scope

PRODUCT CATEGORY	**Material similarity with products currently in the scope**	**Inclusion in other Ecolabels and environmental schemes**	**Interest of stakeholders**	**Global Market relevance 2019 in M USD**	**Market relevance 2019 in M USD (EU 28)**	**Environmental impacts**	**Potential for inclusion**
Reusable baby diapers or nappies							Low
Reusable sanitary pads or towels							Low
Reusable panty liners							Low
Reusable Menstrual cups							Medium
Reusable nursing pads or breast pads							Low

Source: JRC.

2.7.2 Conclusions on the proposal for scope and definition

Based on the information compiled in Table 10 (addressing the assessment potential inclusion in the scope of different reusable product group categories), a new proposal for the expansion of the AHP scope has been determined.

There are no products showing a high potential for inclusion. The products ranked with a low potential for inclusion (reusable baby diapers, reusable sanitary pads, reusable panty liners, and reusable nursing pads) are not proposed to be included in the revised scope. An extension of the scope needs to be considered depending on market interest and environmental improvement potential. Only products for which there is a demonstrated market demand should be included in the product group scope.

Menstrual cups are the only products with medium potential for inclusion as Table 10 shows. The assessment performed sets as a conclusion the proposal to **expand the scope of the AHP EU Ecolabel to reusable menstrual cups**. This is considered due to their market relevance and lower environmental impact, as well as stakeholders' interest.

Therefore, given also the feedback received during the EUEB meeting held in April 2021, it is suggested to propose a revision of the name as follows:

Absorbent Hygiene Products and Menstrual Cups

Moreover, EUEB members were consulted on the need to revise the wording of the product scope description for AHPs. Following their feedback, a new wording is proposed.

The proposed scope is as follows:

> *1. The product group 'absorbent hygiene products' shall comprise any sanitary article whose function is to absorb and retain human urine, faeces, sweat, menstrual fluid and milk - excluding textile products.*
>
> *2. The product group 'menstrual cups' shall comprise reusable flexible cups or barriers worn inside the body to retain and collect menstrual fluid, and usually made of medical-grade silicone, rubber, latex, or elastomer.*
>
> *3. The product groups 'absorbent hygiene products' and 'menstrual cups' shall not include incontinence products and any other type of products falling under the scope of Council Directive 93/42/EEC amended by Regulation (EU) 2017/745[19].*

During the revision, practicability and feasibility of the proposed scope and definitions was assessed in light of other relevant information (market data, technical analysis, feedback from stakeholders, etc…) and further modifications were proposed in the last stages of the evaluation of further information and discussions at the AHWG meetings.

The final proposal for product group is as follows:

Absorbent hygiene products and reusable menstrual cups

While the final proposal for product scope is as follows:

> 1. The product group 'absorbent hygiene products' shall comprise any article whose function is to absorb and retain human fluids such as urine, faeces, sweat, menstrual fluid or milk, excluding textile products.
>
> 2. The product group 'reusable menstrual cups' shall comprise reusable flexible cups or barriers worn inside the body whose function is to retain and collect menstrual fluid, and made of silicone or other elastomers.
>
> 3. The product groups 'absorbent hygiene products' and 'reusable menstrual cups' shall not include products falling under the scope of Regulation (EU) 2017/745.

[19] Council Directive 93/42/EEC of 14 June 1993 concerning medical devices. OJ L 169, 12.7.1993, p. 1–43.

3 Task 2: Market analysis

This section characterizes the European Absorbent Hygiene Products market and its trends at a quantitative and qualitative level for the different categories of this product group. The study outlines the market knowledge in order to support the on-going revision of the EU Ecolabel criteria for the given product group.

Section 3.2 of this report outlines the number of EU Ecolabel licences and products awarded until March 2021. Section 3.3 analyses the state-of-the art AHP market worldwide, introducing global trends and underpinning the importance of these products given by consumers. It also provides updated market data to assess the economic relevance of the AHPs at European level. The information on imports and exports is assessed in section 3.4 whereas section 3.5 identifies the relevant trends, key actors, challenges, innovative products and market segmentations. Section 3.6 looks at distribution channels and consumer options, while section 3.7 provides the key conclusions.

3.1 Methodology

All of the most up-to-date market data presented in this report – if not referenced otherwise – are sourced from Euromonitor International data. This includes: baby diapers (or nappies/pants), panty liners, sanitary pads (or towels) and tampons (all in disposable form – single use). No data on breast pads (nursery pads) were found in the available literature due to the low market value in comparison to the rest of the AHPs. The Euromonitor International's categorisation system will be used for the purpose of facilitating the market data analysis. The Euromonitor categories and their equivalency to the categories already in scope are listed in section 2.5.2.

The market situation for existing reusable alternatives to the disposable AHPs will also be summarised.

Incontinence products are excluded from the market analysis because they fall under the medical devices Regulation, and hence, are excluded from the scope of the product group as indicated at the beginning of this report.

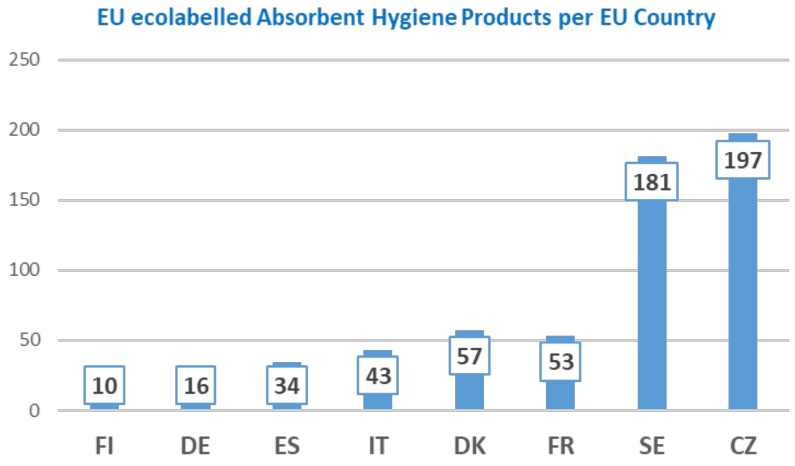
All in all, the following AHPs have been analysed under this chapter of the preliminary report:

- Disposable baby diapers.
- Disposable feminine protection: tampons, pads and panty liners.

3.2 Market penetration of the EU Ecolabel

In 2017 EU Ecolabel licence holders were located in only three countries (Denmark, Finland and Sweden). In September 2023 (last update), the geographical distribution had expanded to eight countries (Finland, Germany, Spain, Italy, Denmark, France, Sweden and Czech Republic) (**Figure 4**).

Figure 4. EU ecolabelled Absorbent Hygiene products per EU country, September 2023



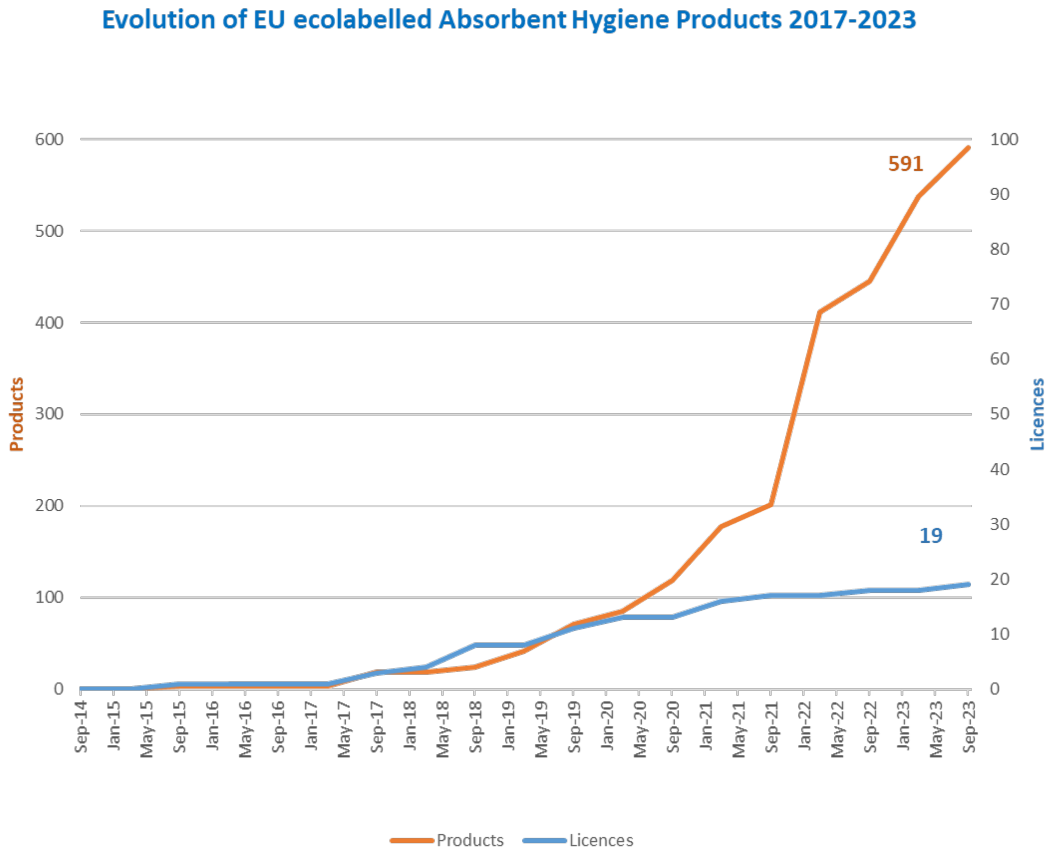
Source: EU Ecolabel Statistics – European Commission[20].

Since the beginning of the AHP group existence (2017), 19 licences have been granted including 591 awarded products.

AHPs are within the segment of product groups with less than 900 certified products. Nonetheless, the trend indicates a steady growth in both the number of licences awarded and the number of EU Ecolabel AHP (**Figure 5**).

[20] EU Ecolabel Statistics – European Commission: https://ec.europa.eu/environment/ecolabel/facts-and-figures.html

Figure 5. Evolution of the number of EU ecolabelled Absorbent Hygiene Products and licenses from March 2017 to September 2023



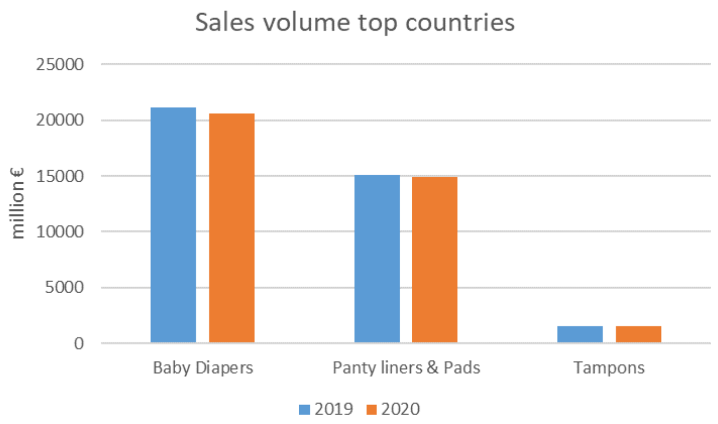
Source: EU Ecolabel Statistics – European Commission[18].

3.3 Sales volume of AHPs

3.3.1 Sales volume in the top countries in the world

As illustrated in **Figure 6**, the sales volume of AHPs within the scope of this project (excluding breast pads) was valued (only for the top countries in the world). For baby diapers sales volume, the top countries were China, the USA, Mexico, Brazil, Indonesia and Japan. Looking at panty liners and pads, the top countries were China, the USA, India, Japan and Russia. While for tampons, the top countries with the highest sales volume were the USA, Germany, the UK, China, Canada and Japan. The largest share of the market belongs to baby diapers (over 55% of the AHP market in both years), followed by feminine panty liners and pads (around 40% of the total AHP market). The tampons' share of the total AHP market was about 5% for 2019 and 2020.

Figure 6. Sales volume in the top countries in the world for 2019 and 2020



Source: Euromonitor International: Tissue and Hygiene industry edition 2021.

Other sources estimated the global baby diapers market size at USD 52.6 billion in 2019 (Allied Market Research, 2021) and a global market for panty liners and pads valued at USD 23.63 billion in 2020 (Imarc Group, 2021). Tampons accounted for around USD 2.82 billion USD in 2018 (Allied Market Research, 2021).

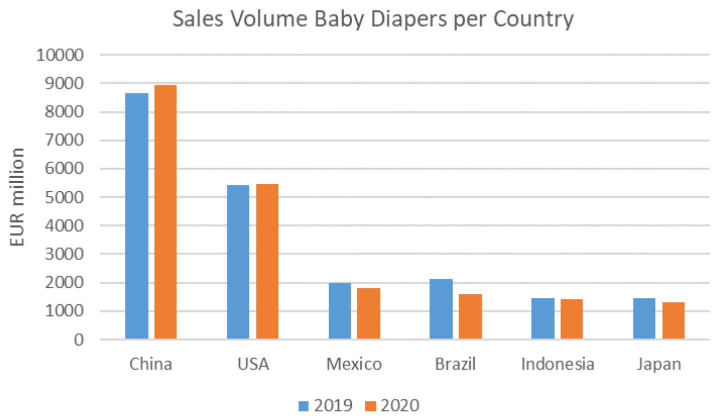
As depicted in **Figure 7 (a)**, for the analysed years China leads the world sales volume for baby diapers in both years, followed by the USA, (then Mexico, Indonesia and Japan). Brazil has experienced a stronger decrease with a decline in growth of just less than 25% between 2019 and 2020.

Figure 7 (b) shows the data for panty liners and pads where China occupied the number one sales position for both 2019 and 2020. USA sales volume for panty liners and pads remain stable while India, Japan and Russia do not exceed the USD1bn mark.

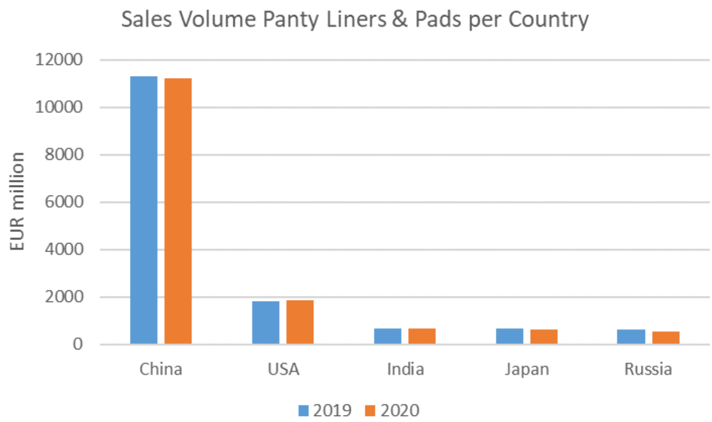
Tampons sales volume also offer an overview of consumer preferences where Germany and the UK are among the world leading consumers in second and third position, respectively. It can be highlighted that in case of China the sales volume of tampons increased over 30% from 2019 to 2020. Figure 7(c) shows the USA being the world leading country in the sales volume of tampons in 2019 and 2020. In Europe, German market reached over EUR 150 million in both years, whereas the UK sales volume was over EUR 100 m (2019 and 2020).

Figure 7. (a) Sales volume in the top world countries for baby diapers in 2019 and 2020. (b) Sales volume in the top world countries for panty liners and pads in 2019 and 2020. (c) Sales volume in the top world countries for tampons in 2019 and 2020

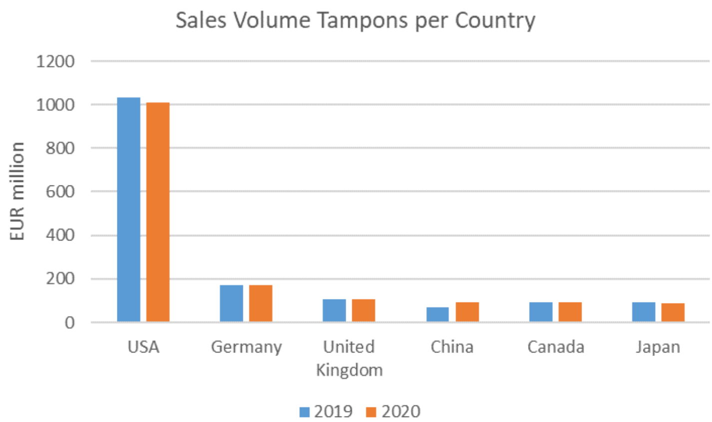
(a)



(b)



(c)



Source: Euromonitor International: Tissue and Hygiene industry edition 2021.

3.3.2 Sales volume in Europe

Figure 8 (a) and (b) represent the EU-27 and the UK' sales volume in monetary (millions of EUR) and unit (millions of units) values, respectively. The analysis addresses the AHPs within the scope of this project (i.e. baby diapers, panty liners and pads, and tampons, excluding breast pads) for each year from 2010 to 2020.

Based on **Figure 8 (a)**, the total AHP sales volume in Europe was valued at just over EUR 6 bn in 2020 representing a volume of around 59 bn units (**Figure 10 (b)**).

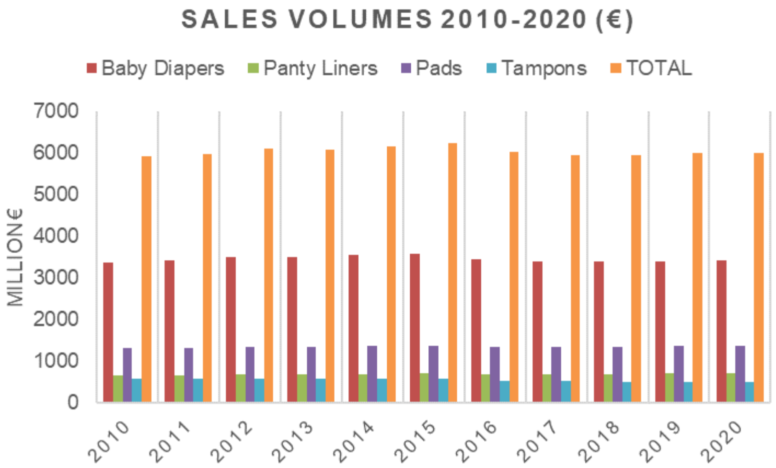
As depicted in Figure 8(a), the largest share of the sales volume belongs to baby diapers (close to 60%) followed by feminine care pads (just less than 25%), and panty liners (just over 10%). The tampons' share of the total sales volume is below 9% corresponding. Compiled data for pads and panty liners represents just less than 35% which is below worldwide average due to the increase in tampons consumption in Europe.

According to **Figure 8 (b)**, from the 59 billion units of AHP sold, the largest market share corresponds to baby diapers (around 35% of the market volume), followed by panty liners (30%). Feminine care pads represent just less than 25% of the market share while tampons with a total volume of nearly 10% of the market share. Compiled data for pads and panty liners represents less than 55% of the AHP market share.

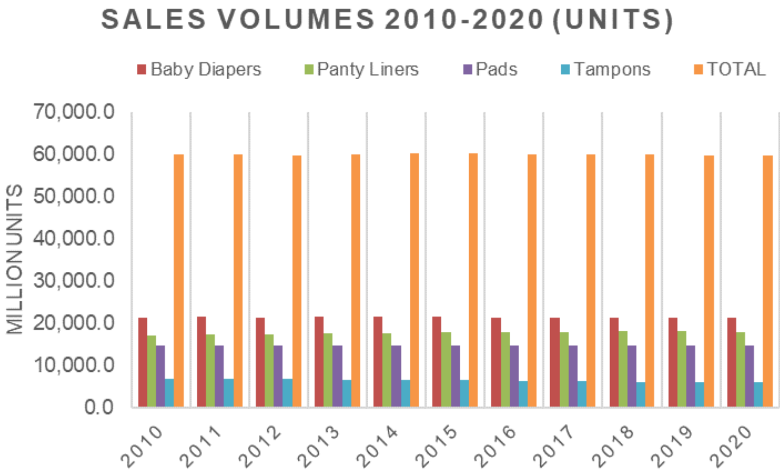
It is worth noting how the price influences the shares depending on the studied system of measurement. For instance, baby diapers represents a 35% market share in number of units while in monetary value reaches nearly 60%, thus highlighting the higher price of the product itself. A similar trend is observed, for tampons and pads. By contrast, for panty liners, the just less than 25% of the value market share corresponds to the 30% of the sold volume market share.

Figure 8. (a) Sales volume of AHPs by product group in EU-27 and the UK in monetary value (EUR) for 2010-2020 (b) Sales volume of AHPs by product group in EU-27 and the UK in units for 2010-2020

(a)



(b)



Source: Euromonitor International: Tissue and Hygiene industry edition 2021.

3.3.3 European AHP sales volume by member states

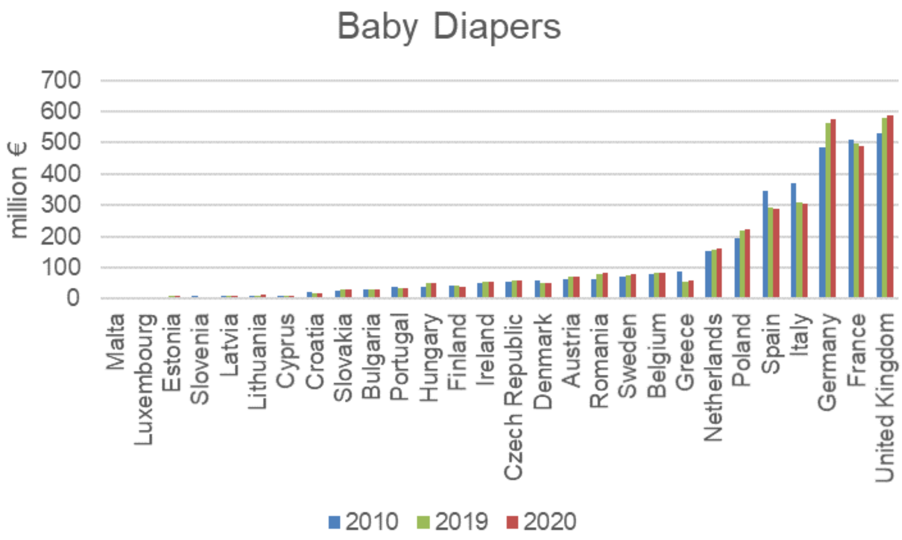
Geographical market segmentation in EU-27 and the UK shows the main consumers of AHPs within the scope of this project (excluding breast pads).

From **Figure 9** to **Figure 12** the AHP sales volume is depicted by EU member states (including the UK), within each analysed product (in m of EUR) for years 2010, 2019 and 2020. This illustrates the year-on-year variation, if any, from the ten-year range perspective but also highlights the product-specific sales volume changes during the last two years.

Figure 9, relating to baby diapers, shows that the UK, France, Germany, Italy, and Spain were the top five consumers in 2010, thus totalling over 65% of the sales. In 2020, the UK maintains the leading position on the market, whereas Germany has recently replaced France in second place. The market sales volume for Spain, Italy and France has decreased within the last five years.

The split of % of the top five country sales accounted for over 65% of the total in 2020, as follows: the UK represents over 17% of the total sales; Germany nearly 17%; France just less than 15%; Italy is close to 10 whereas Spain accounted for over 8%. Poland represents over 6% while the rest of countries are below the 5% mark of the total sales volume of baby diapers.

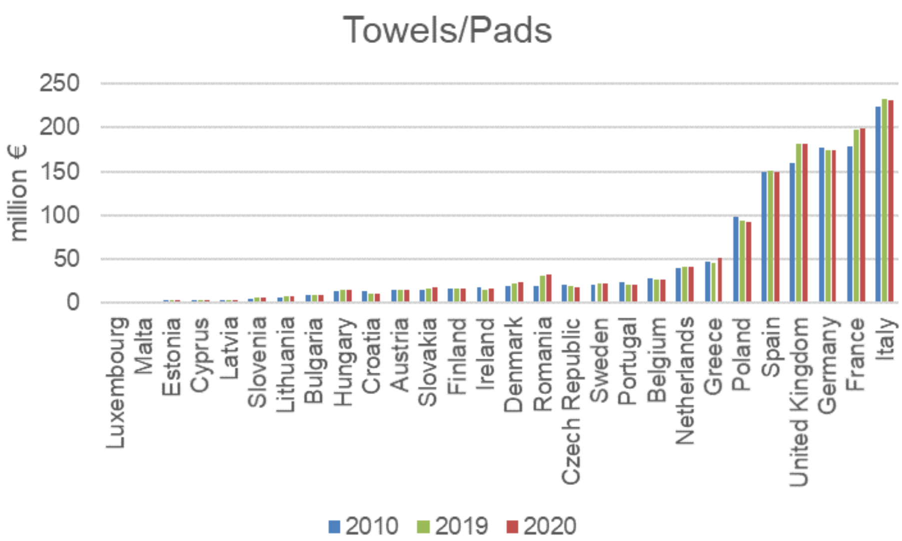
Figure 9. Sales volume of baby diapers per member state for 2010, 2019 and 2020



Source: Euromonitor International: Tissue and Hygiene industry edition 2021.

Feminine care pads are the second AHP in sales volume within the EU-27 and the UK (**Figure 10**). The top five countries with the highest market share are Italy, France, Germany, the UK and Spain. These data highlight the existing correlation with the population size and related percentage of menstruating women but also shows the consumption behaviour. Italy leads the volumes sales for all the considered years (2010-2020) with a market share of nearly 17% in 2020. France accounts for over 14%, the UK for around 13% (Germany for just over 12% (it was number 3 in 2010 and for 2019 and 2020 the UK overcome it), Spain (over 10%) in the sixth position, Poland volumes sales represented close to 7%. As in the baby diapers market, the rest of country values are below the 5% of the total sales volume of sanitary pads.

Figure 10. Sales volume of pads per member state for 2010, 2019 and 2020

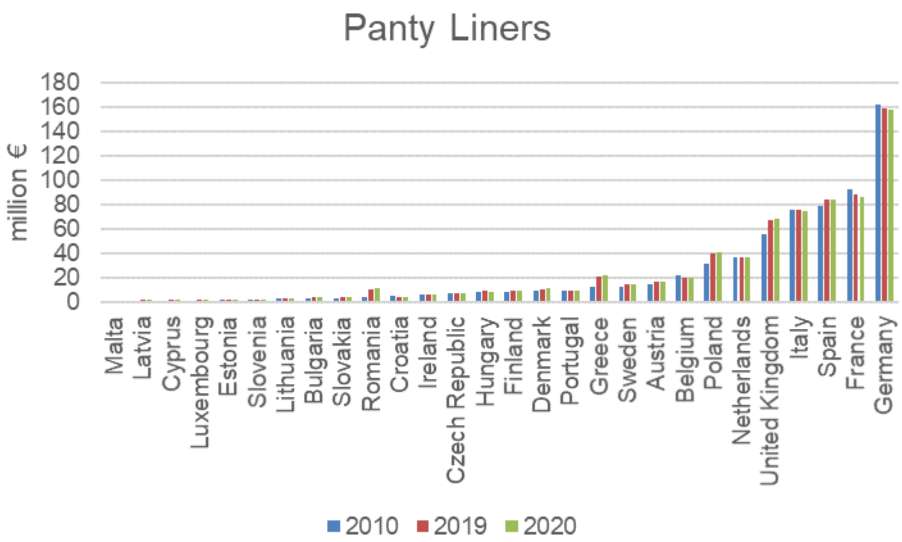


Source: Euromonitor International: Tissue and Hygiene industry edition 2021.

With regards to panty liners, sales volume within the EU-27 and the UK (**Figure 11**) represent a total of over EUR 700 m with the top five countries being again Germany, France, Spain, Italy and the UK. Poland and The

Netherlands have similar values. Germany leads the volumes sales for all the considered years (2010-2020) with a market share of over 20% in 2020. France relates to over 12%; Spain 12%; Italy over 10%; and the UK over 9%. In 2019, the sixth position corresponds to the Netherlands while in 2020, Poland takes the mentioned position. The rest of the country values are below 5% of the total sales volume of panty liners.

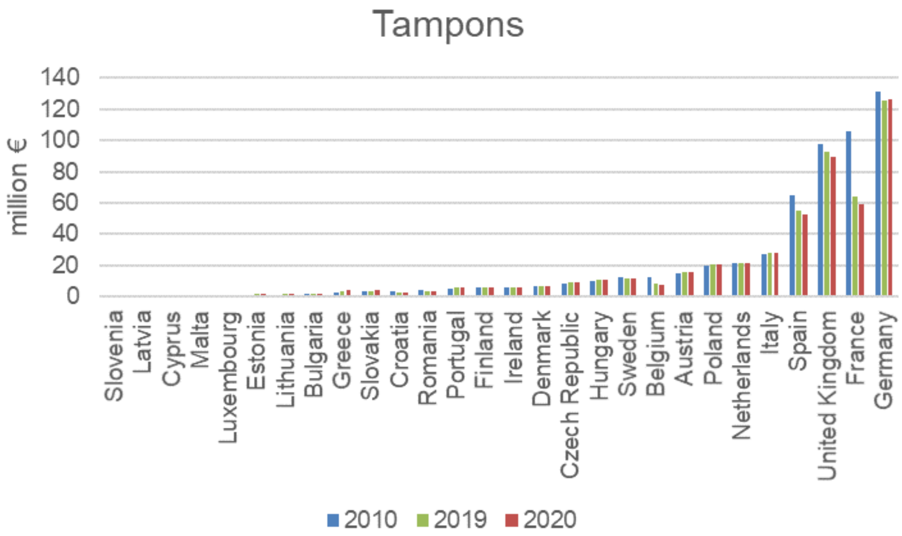
Figure 11. Sales volume of panty liners per member state for 2010, 2019 and 2020



Source: Euromonitor International: Tissue and Hygiene Industry Edition 2021.

Germany, France, the UK, Spain and Italy are the countries with the highest sales volume of tampons for the period 2010-2020 (**Figure 12**). Germany, Italy and countries such as the Netherlands, Poland, Austria or Sweden have kept the sales stable during the analysed period of time. A change in consumer's behaviour might be observed in Spain and France with a 19 and 40% decrease of tampons sold from 2010 to 2020. Germany leads the volumes sales with over 25% of the market share in 2020. The UK was in the third position in 2010 and escalated to the second position in 2019. In 2020, the UK sales accounted for nearly 18% sales volumes of tampons. The volume sales of the European tampon market share reached for France nearly 12%); for Spain just over 10%) and for Italy slightly over 5%. Volume sales for tampons were below 5% for the rest of countries.

Figure 12. Sales volume of tampons per member state for 2010, 2019 and 2020



Source: Euromonitor International: Tissue and Hygiene industry edition 2021.

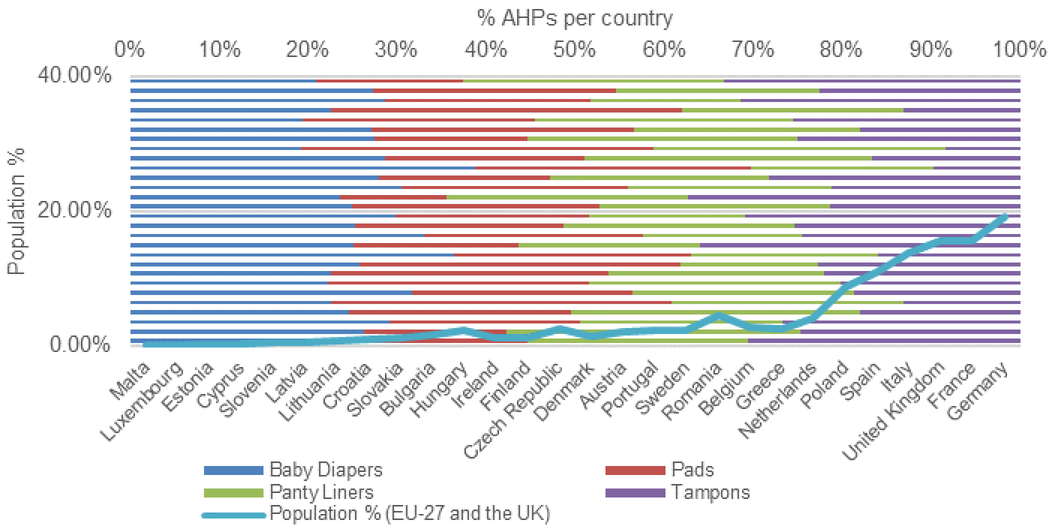
These data can also be compared with data in **Figure 13** where the percentages for each of the EU-27 and the UK are summarised and compared to the EU population on 1st January 2020 (blue line) (Eurostat, 2021).

From Figure 13 it can be derived that the sales volume of the products within the scope of this project are very closely related to the Member State's population. Regardless of which country is analysed, the difference between the share of population in the EU-27 (and the UK) and the overall share of AHP sales is never greater than 2%.

Another result from the country-specific analysis of the market sales volume is that the ten most populated EU-27 countries together with the UK reached nearly 85% of the AHP sales volume.

Last but not least, differences might be observed at the level of the users' behaviour, i.e. in Italy the use of tampons is comparatively low when contrasted with Germany, the UK or France.

Figure 13. Sales volume percentage of AHPs by EU countries and population (people and % share) in 2020



Source: Euromonitor International: Tissue and Hygiene industry edition 2021 and Eurostat.

3.4 Import and export figures of the AHP sector

For the purpose of the project, it is of interest to understand the intensity of the market trade. **Table 11** provides information necessary to shed some light on the AHP import/export and production figures. It is important to note that the PRODCOM categories 17.22.12.10, 17.22.12.20 and 17.22.12.60 provide highly aggregated data, therefore the information included in **Table 11** should only be referred to as an estimate[21].

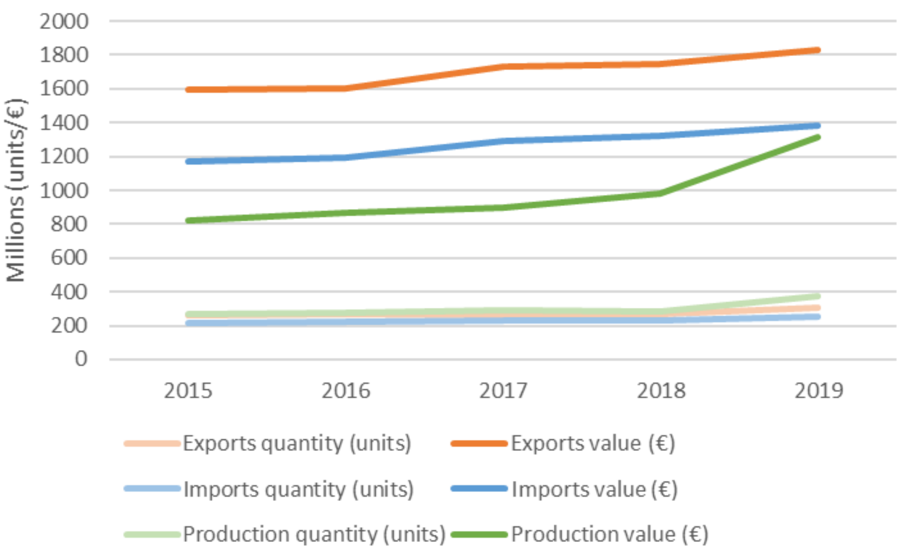
The total values (Table 11) are provided with respect to the EU-27 and the UK for years 2015 to 2019 in regards to export, import and production in volume (units) and value (EUR). **Figure 14** shows the trends where it is observed that exports, imports and production increased during the five-year-period in 15%, 18% and 60% respectively (for the monetary value in EUR).

Table 11. Exports, imports, production and % growth for EU-27 and the UK (2015-2019)

TOTAL (millions) per year	Exports quantity (units)	Exports value (EUR)	Imports quantity (units)	Imports value (EUR)	Production quantity (units)	Production value (EUR)
2015	261.38	1,597.26	216.03	1,168.96	269.45	817.98
2016	268.80	1,604.79	219.58	1,193.16	277.94	863.46
2017	263.67	1,731.54	228.91	1,294.63	291.90	895.20
2018	269.26	1,748.75	233.12	1,320.69	284.47	978.58
2019	307.76	1,831.49	252.22	1,380.73	376.47	1,310.57
5 year growth	18%	**15%**	17%	**18%**	40%	**60%**

Source: PRODCOM.

Figure 14. Exports, imports and production for EU-27 and the UK (2015-2019)



Source: PRODCOM.

[21] PRODCOM categories: 17.22.12.10 - Sanitary towels and tampons, napkins and napkin liners for babies and similar sanitary articles, of wadding, 17.22.12.20 - Sanitary towels, tampons and similar articles of paper pulp, paper, cellulose wadding or webs of cellulose fibres and 17.22.12.60 - Sanitary towels (pads), tampons and similar articles, of other textile materials (excl. of wadding of textile materials).

One observation that can be made from the analysis is the export value and volume is higher than the import figures for all studied years. However, both, exports and imports tended to increase in the last years with imports value having augmented slightly. It has been noticed that in 2019, a stronger increment also occurred to the production of AHPs, mainly in monetary value.

According to AHP suppliers, most of the imported AHPs come from Northern Africa or the Middle East. The Middle East may most likely also be the recipient of exported AHPs. Other sources cite that the European area is a net exporter of menstrual products such as pads. The majority of baby diapers used in the EU are produced within Europe. However, it must be taken into account that some of the resources used in the production of these products are not produced within the EU geographical area (Cabrera and Garcia, 2019). For instance, according to manufacturers of fluff pulp, 90% of the global production of this material takes place in North America with an average transportation distance of over 2,000 km from Europe (Mendoza et al., 2019).

3.5 Structure of the AHP sector

3.5.1 Global key actors and brands

The main producers and key brands are summarised in **Table 12** for a better knowledge of the market lead players. The two key companies for AHPs in 2011 and 2020 were Procter & Gamble (P&G) and Kimberly-Clark Corporation. The main brands for baby diapers are Pampers (from P&G) and Huggies (from Kimberly-Clark Corporation) while for feminine care pads are Always/Whisper (also from P&G).

Table 12. Global key actors and brands in 2011 and 2020

Top AHP producers in 2011	Top AHP producers in 2020
1. Procter & Gamble (P&G) 2. Kimberly- Clark Corporation 3. Private non-disclosed label 4. Unicharm Corporation 5. SCA Group 6. Johnson & Johnson (J&J)	1. Procter & Gamble (P&G) 2. Kimberly- Clark Corporation 3. Private non-disclosed label 4. Unicharm Corporation 5. Essity AB 6. Kao Corporation
Key brands AHP in 2011	**Key brands AHP in 2020**
1. Pampers (from P&G) 2. Huggies (from Kimberly- Clark Corporation) 3. Private non-disclosed label 4. Always/Whisper (from P&G) 5. Kotex (from Kimberly- Clark Corporation) 6. Tena (from SCA Group)	1. Pampers (from P&G) 2. Private non-disclosed label 3. Huggies (from Kimberly- Clark Corporation) 4. Always/Whisper (from P&G) 5. Sofy (from Unicharm), 6. Mamypoko (from Unicharm)

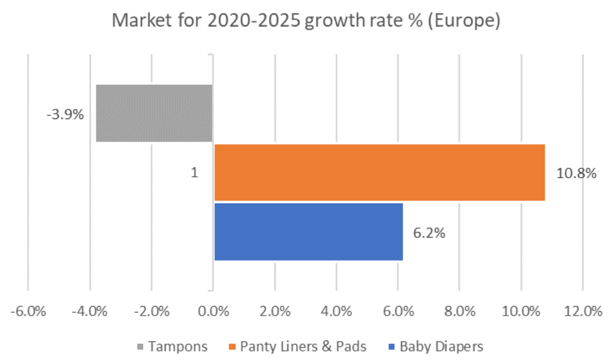
Source: Euromonitor International: Tissue and Hygiene industry edition 2021.

3.5.2 EU and World AHP forecast

Based on sales within the EU-27 and the UK, the AHP[22] sales volume slightly decreased between 2010 and 2020. A more detailed analysis of the market development per product type over the last ten years provides some interesting insights, e.g. the decrease in sales volumes can be mainly attributed to a reduction in tampon sales volumes while an increment in baby diapers and a nearly steady state for panty liners and pads sales volume was observed.

Figure 15 represents the global forecast for Europe for the timeframe 2020-2025. The expected growth rate for AHPs regarding panty liners and pads is up to 10.8% while for baby diapers the increment would be of just over 6%. A decrease of nearly 4% in the tampons market is expected in the next years. The alternative for more sustainable products may play a role in this regard thus favouring the utilisation of reusable pads and menstrual cups although a change in hygienic protection can also be expected. IFOP (2021), conducted a survey among a sample of 1,009 women, representative of the French female population aged 15 to 49 years old and they found out an evolution of methods of hygienic protection. The IFOP study showed a growing disavowal of tampons: 19% of menstruating women use them today, against 33% in 2003, a drop of 14 points in 18 years. Indeed, the youngest seem to turn more to forms of external protection such as sanitary pads, which are easier to access and use, or alternative modes of protection, known for their respect for the female body, their composition or the ecological aspect (e.g. period underwear…) (IFOP, 2021).

Figure 15. Europe global AHP forecast 2020-2025



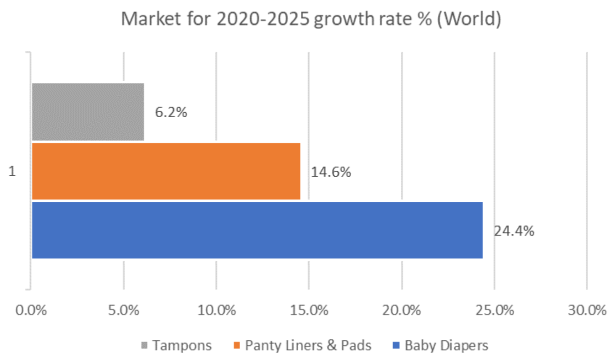
Source: Euromonitor International: Tissue and Hygiene industry edition 2021.

It is worth noting that the interpretation of these data should be handled with caution because it cannot be guaranteed this will be the global trend for the next given years.

The world market growth 2020-2025 forecast provided different data as it predicts the increment in all the AHP considered. In this case, worldwide data illustrate an increment of 6.2, 14.6 and 24.4% for tampons; pads and panty liners; and baby diapers, respectively (**Figure 16**).

[22] Refers to the AHPs included in the scope of the product group, for more detail please see chapter 2.

Figure 16. Worldwide global forecast 2020-2025



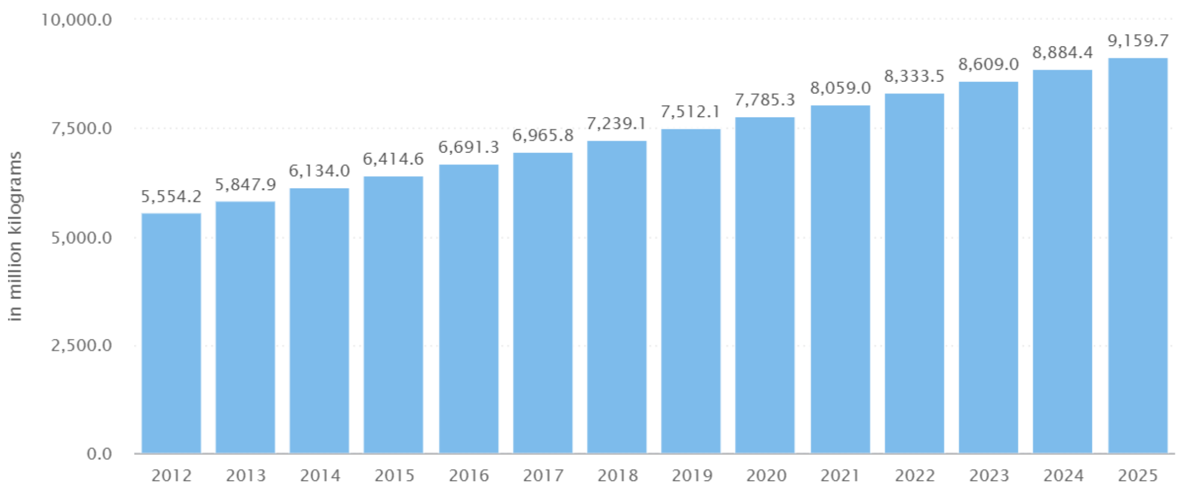
Source: Euromonitor International: Tissue and Hygiene industry edition 2021.

Market dynamics for baby diapers

The segmentation of the global market for baby diapers generally distinguishes disposable, cloth and the so-called biodegradable baby diapers. According to figures from Euromonitor International, in 2019, the value of the global baby diaper market was USD 43.38 bn (Nonwovens Industry, 2020), reaching an annual market demand for disposable baby diapers of 20 billion units (690 kt) in the European Union (Mendoza et al., 2019).

The disposable baby diapers market share exhibits a rising trend with an expected annual growth of 3.9% (Compound Annual Growth Rate- CAGR 2020-2025) (Statista, 2020) with an expected increase in volume up to 9,159.7 m kg by 2025 (Today Kansas, 2020) (**Figure 17**).

Figure 17. Global baby diapers volume growth



Source: Today Kansas, 2020.

Others sources estimate that some 33 billion single-use baby diapers per year are to be consumed in the EU alone (Cabrera and Garcia, 2019). These numbers continue to rise, with the global baby diaper market expected to exceed USD 71 bn by 2022. The growth is fuelled by the high birth rate in developing countries coupled with improving economies and urbanisation, along with increased availability and marketing, amongst other factors (Khoo et al., 2019).

Nowadays there is a high diversity of baby diapers in the market sold as environmentally friendly. The most of them include the FSC logo while many include TCF claims or absence of hazardous substances. Some of these options are shown in **Table 13** where a screening of a well-known hypermarket options is summarised. The purpose of **Table 13** is to offer a quick overview rather than being fully comprehensive.

Table 13. Disposable baby diaper market screening

Product Name	FSC claim	TCF claim	EU Ecolabel	Other claims
Carrefour Baby	Yes	No	No	Oeko-Tex 100
Love and Green	Yes	Yes	Yes	100% chlorine, petrolatum, coloring free. Made using natural material (sugar cane)
Pampers	Yes	No	No	No. 1 Confort
Carrefour BABY Ecoplanet	Yes	Yes	Yes	0% lotion, fragance, Chlorine bleaching
Lotus Baby	Yes	No	Yes	0% lotion, fragance, coloring, allergens.
Pampers Harmonie	Yes	No	No	0% lotion, fragance Hypoallergenic Oeko-Tex 100
Biolane	Yes	Yes	No	0% lotion, fragance, Chlorine bleaching, allergens, pesticides.

Source: Carrefour, 2021.

The non-disposable diapers still have a lower global market share compared to the disposable baby diapers (Grand View Research, 2018). The development of the cloth diaper market has been hindered due to their lower absorbent capacity that translates into a more frequent replacement, cleaning, and a higher possibility of leakages (Cabrera and García, 2019). Nonetheless, disposable baby diapers are expected to witness competition by cloth diapers in the coming years as new material innovation are put in place (Allied Market Research, 2021).

On the other hand, reusable diapers require quite a larger upfront investment. A starter kit generally consists of 24 reusable diapers liners and lengtheners for bodysuits and is an investment of around EUR 400 and to pay such amount upfront can be a barrier for some customers (OVAM, 2018).

The market growth of sustainable nonwovens (nonwovens from renewable and/or biodegradable materials) slowed down significantly in 2016. During 2012 and 2017 sustainable nonwovens grew 50-70% faster than all nonwovens but projected growth for sustainable nonwovens 2017-2022 is only +3% in tonnage (OVAM, 2018).

From 2016 to 2020, the baby cloth diaper market reflected stagnated growth of 2.1% CAGR- Compound Annual Growth Rate (while a recently released study has forecasted the global baby cloth diaper market to continue rising at close to 2% CAGR from 2021 to 2031). The essential nature of diaper products has allowed cloth diaper production and sales to remain unaffected by the COVID-19 crisis, which affected the globe through 2020. The trend is unlikely to change through the projection period as well. Disposable baby diapers are available in a larger variety of options, which also include greener disposable diaper innovations (such as introduction of biodegradable or recycled materials), threatening the sales of cloth diapers. On the other hand, the common use of wood pulp and synthetic materials in disposable baby diapers also generates environmental concerns. Modern cloth diapers are being produced with a reusable, waterproof plastic material, with absorbent materials made from natural fibres of bamboo, cotton, or hemp. Also, the introduction of cloth baby diaper banks for the resale of used cloth diapers for poor families has bolstered the popularity and adoption of baby cloth diapers. One example can be found in St. Louis Missouri (USA), where a company specializing in reusable products announced the start of its cloth diaper bank initiative (Fact. MR, 2021).

Market dynamics of feminine hygiene products

The global market data for disposable feminine hygiene aggregates different products, besides pads, panty liners and tampons (data shown in previous section), sprays, internal cleaners, and reusable products can be found. In general, the global feminine hygiene products market size reached USD 26.0 bn in 2019 and it is expected to reach USD 37.2 bn by 2025, catalysed by a shift toward eco-friendly variants (Imarc Group, 2017).

As illustrated, pads hold the largest market share with a revenue of USD 20.5 bn in 2018 (Statista, 2020). According to several sources, the CAGR has been projected for this product between 6.2-6.5% per annum (Benzinga, 2019; Nonwovens Industry, 2020; Imarc Group, 2020) while the global tampon market size accounted for around USD 2.82 bn in 2018 registering a CAGR of 4.7% m USD until 2026 (expecting to reach USD 4 bn USD by 2026) (Allied Market Research, 2021).

Emerging countries for the market of tampons are from the Asia-Pacific region with a growth rate of 5.8%. China and Australia markets are expected to grow at a CAGR of 5.7% and 6.4% respectively. The North America market held a major share in the tampon market in 2018 and is expected to continue the trend in the forecasting period up to 2026. The key trends in the tampon market seems to be the introduction of 100% organic tampon due to rise in consumer demand for chemical-free products. Most key players maintain strategic focus on new product development, sustainable products or patents on new technology. The global tampon market is dominated by a few major players such as Svenska Cellulosa AB, P&G, Edgewell Personal Care Company, Kimberly-Clark Corporation or Unicharm Corporation (Persistence Market Research, 2021).

In the same way feminine care pads labelled such as organic cotton 100% with no plastics can be found in the market nowadays. The main disposable organic menstrual pads are Natracare, Honest Co., Organyc, Maxim and NatraTouch (Menstrual Cups reviews, 2021). The mentioned brands also manufacture 100% organic cotton tampons (Menstrual Cups reviews, 2021).

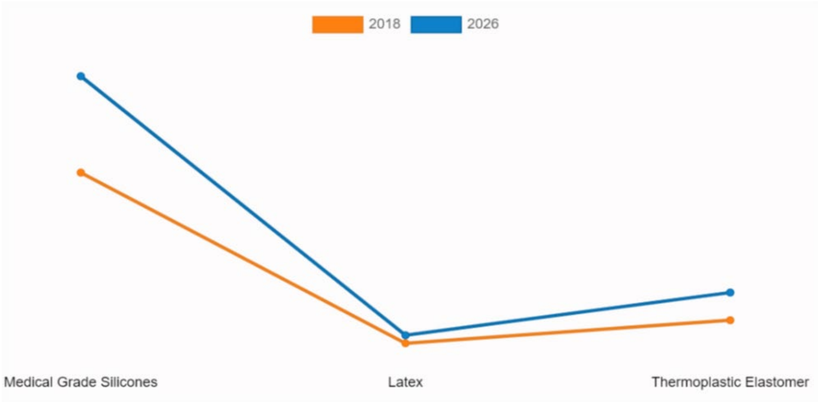
Regarding reusable menstrual feminine hygiene products, menstrual cups, period underwear (or menstrual panties) and reusable menstrual cloth pads are the three main products available in the market.

In countries like the UK where the popularity of these products is growing, reusables already make up 5% of the menstrual products market. Some producers have reported that sales have been growing at double digit rates over the last 10 years (Cabrera and Garcia, 2019).

According to some sources, the menstrual cups market in Europe is anticipated to reach USD185.19 m by 2027 from USD124.43 m in 2019 while at a global level, the menstrual cup market accounted for around USD632 m in 2018. The global market is projected to grow at a CAGR of 5.2% during 2020–2027 (Report Linker, 2020).

Menstrual cups are made of various materials, such as silicone, rubber, and thermoplastic elastomer (TPE). Silicon (medical grade) and thermoplastic elastomer are hypoallergenic which makes these types of menstrual cups the most demanded. However it has been reported that TPE menstrual cups present less allergy incidences (Chin, 2020). Based on material type, the TPE segment is expected to experience rapid growth in the market and is projected to grow at a highest CAGR from 2019 to 2026 (Research and Markets, 2020). Reasons for TPE market growth could be related to their lower price, easier (although more energy-intensive) manufacturing process and a better fit for use. A drawback of TPE menstrual cups is durability, in general of three to five years while medical grade silicone cups can last from five to ten years. Silicone cups also keep their shape for longer (Bolen, 2020). Based on material type, the medical grade silicones segment is the major contributor toward the menstrual cup market share attributable to the rise in demand for safe, durable, and non-allergenic products. However, the demand for thermoplastic elastomer as material for menstrual cup is expected to increase during the forecast period due to its cost-effective tooling and ability to be recycled (Allied Market Research, 2020). **Figure 18** shows the comparison of menstrual cup market by type of material in 2018 and its expected market growth in 2026.

Figure 18. Menstrual cup market by material type of material, 2018-2026

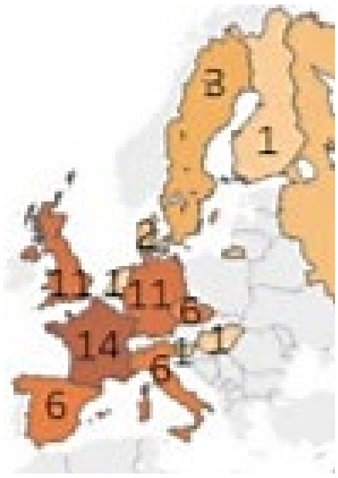


Source: Allied Market Research, 2020.

The menstrual cup is rising in global popularity, but remains a fringe product with a global market growth of 4% per year. However, menstrual cups are reusable and can last up to ten years (Desrosiers, 2020), this means one can buy it and use it for five to ten years when you buy neither tampons nor a new menstrual cup. This shows the low uptake of menstrual cups might not reflect the use. It is to note that menstrual cups are also available in a disposable option which can be used for up to 12 hours however with a much lower market share (Allied Market Research, 2020).

Eijk et al., (2019) found 199 brands of menstrual cup, and availability in 99 countries (median 145 brands in 32 countries). Generally, menstrual cups can be found everywhere in Europe for online purchase but, for a direct purchase, it is limited in pharmacies, supermarkets and local commerce. As **Figure 19** shows, the number of menstrual cups' brands reported to be based in each country is led by France (14) and Belgium and the UK (11 each) (Desrosiers, 2020). The main menstrual cups brands found in the market are Moon Cup, BeYou, Saalt, SPEQUIX, Merula or DivaCup (Whitbread and Belamant, 2021).

Figure 19. Number of menstrual cups' brands reported to be based in each country



Source: Desrosiers, 2020.

The menstrual underwear market is expected to grow very strongly with a CAGR of close to 16% through the end of 2030. The global growth in health awareness for females, the rise in the number of working women, and the relative convenience as compared to other menstrual products are key factors that support long-term market growth (AP News, 2021).

It is worth noting that period underwear is a more expensive option than the menstrual cup as multiple pairs are needed to cover one monthly cycle (most period underwear absorbs up to 2 tampons' capacity). Menstrual cups can be worn for up to 12 hours having to empty it more frequently during the heavier days of the period however only one unit is used for the whole cycle (Khilnani, 2018). Market forecasts comparing both period underwear and menstrual cups have not indicated whether period underwear or the menstrual cup market shares are higher.

Cabrera and Garcia (2019), listed 31 and 26 manufacturers distributing reusable menstrual cloth pads and menstrual cups, respectively, in Europe. The volume of sales of two of the main menstrual cup manufacturers in Europe was around 250,000 units in total in 2018. Estimating the volume of sales of reusable menstrual cloth pads in Europe is much more difficult as most of them are produced by local and small manufacturers. In 2018 three manufacturers distributed together about 60,000 units in Europe (Cabrera and Garcia, 2019).

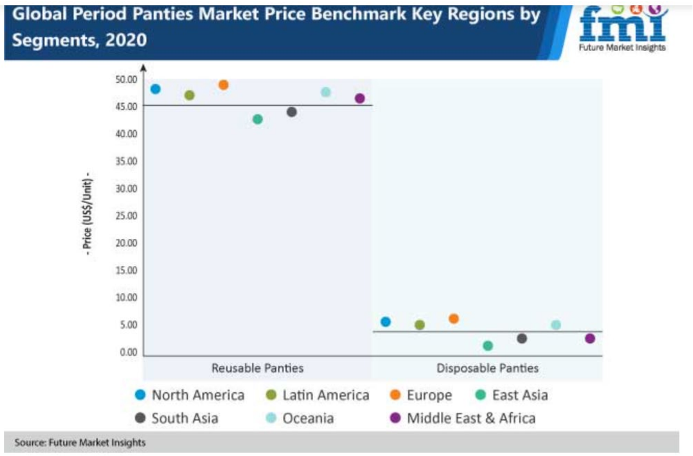
As Cabrera and Garcia (2019) identified, the increasing number of Google searches for reusable products is indicative of their growing popularity, with the menstrual cup proving the most popular.

As an FMI (Future Market Insights) study points out, the efforts made by manufacturers towards product innovation regarding menstrual underwear design are anticipated to boost the market for the assessment period. Further, environmental concerns about waste arising from products such as single use pads and tampons will also boost the adoption of reusable period options in the long-term (Future Market Insights, 2021).

A country- wise analysis (**Figure 20**) shows that Germany is the second largest period underwear market in Europe. Favourable government policies have been driving growth in Germany. For instance, the country has reduced tax on sanitary items from 19% to 7% from January 2020 onwards. Such regulations are creating a conducive environment for expansion of the period underwear market in Germany. Additionally, the scrapping of ‘tampon tax’ by Germany on menstrual hygiene products which used to be 19% till the summer of 2019, has worked as a significant driver for the period underwear market in Germany since then. Similar initiatives are catalyzing the growth of the period underwear manufacturers as they are experiencing rise in demand for the same all over Italy and France mainly (Future Market Insights, 2021). It has been reported that period underwear can last from two to five years in function of material, frequency of use and care (La casa del bambú, 2021).

Some of the key market players for period underwear are Knixwear, Lunapads International, Modibodi, Flux, Anigan, Clovia, Thinx, Yashram Lifestyle, Fannypants LLC, Pantyprop, Harebrained, Period Panteez, WUKA (Future Market Insights, 2021) with even fast fashion retailers as Primark/Penneys recently launching a line of period underwear (Primark, 2021).

Figure 20. Global period panties market price benchmark key regions (2020)



Source: Future Market Insights, 2021

Market dynamics of reusable nursing pads

Demand for reusable nursing pads (breast pads) is increasing as it offers comfortable solutions to the mothers. The organic bamboo fabric is increasingly becoming favourable to use for the manufacturing of the reusable nursing pads as it associates with offering more absorption properties and are ultra-soft. Other popular fabrics used for the reusable nursing pads are cotton and polymer. The prominent manufacturers of reusable nursing pads are also offering reusable nursing pads with latex and gluten-free properties (Future Market Insights, 2021).

Some of the key players of reusable nursing pads market are Medela Industries, Lansinoh, Johnson & Johnson, Bamboobies, Lily Padz, Kindred Bravely, Eco Nursing Pads, Mother Ease, Pigeon or Ameda. No substantial market data were found for breast pads either disposable or reusable (Future Market Insights, 2021).

Market of AHP materials

Market data for materials used in AHPs such as SAP (super absorbent polymers), fluff pulp and alternatives are also of interest.

SAP is a synthetic material derived from petroleum, manufactured primarily as granular sodium polyacrylate, produced by the polymerization of acrylic acid with ammonium persulfate as initiator that can absorb and retain very huge quantities of liquids. It was reported that 1 kg of SAP can absorb up to 418 L of water. The granular form of SAP has proven to have the ability to raise the retention capacity of disposable baby diapers (DBD) to absorb and retain liquid up to 100 times their weight. DBDs were the largest application segment in 2018 and the global market for baby diapers is expected to grow by more than 6% by 2022 maintaining its dominance until 2025 as referred to before. Consequently, this market growth will have a direct impact on the superabsorbent market. In fact, DBDs accounted for more than 74% of the USD 7.1 billion global SAP market with a production rate of 2119 million tons in 2014 (Bachra et al., 2020). Indeed, the size of the global SAP market is expected to reach USD 12.10 billion by 2025, according to recent estimates, with a compounded annual growth rate of 6.3% over the forecast period. Similarly, the size of the polyacrylic acid market is expected to grow by more than 6% by 2025 (Grand View Research, 2019). On a regional basis, with Europe dominating the global SAP market in 2018, a growth of 5.4% is expected over the forecast period.

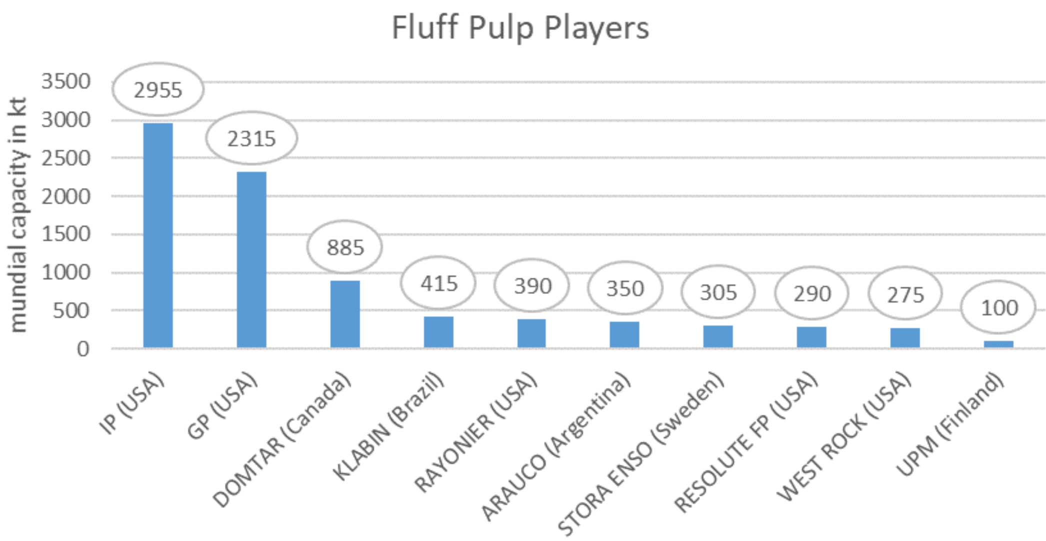
The SAP market is of a consolidated nature and is characterised by the presence of a large number of global and regional players. From an economic development perspective, these players are focused on expansion through joint partnerships, mergers, acquisitions, and strategic alliances due to the increase in product applications, which can amplify market growth. During 2020, the economic conditions the world faced because of the COVID-19 pandemic created global petroleum price wars, which had an economic impact worldwide. One of the consequences was a lower petroleum derivatives prices (Oil and Gas, 2020), whereas among these derivatives, is polyacrylic acid, the most widely used common product as SAP in DBD. Henceforth, decreases in the prices of baby diapers may be foreseen.

Fluff pulp is a chemical pulp made from long fibre softwoods. Fluff pulp is used primarily in AHPs with the demand to grow steadily at 3-4% per year. Most of the fluff pulp in the world is produced in the USA (84%) (Cavanagh, 2018). Worldwide data show the existence of at least 24 pulp mills, operated by 13 companies, located in six countries, where the 99% of fluff pulp is made using softwood fibres, utilising the kraft process (Cavanagh, 2018). Currently Latin American kraft fluff pulp production stands outs as the third largest global producer with an annual production of 475 000 tons having as differentiator the lowest production cost and better yield. The main fluff pulp producers are originally from the USA or Canada while in the top ten producers, European companies such as Stora Enso (Sweden) and UPM (Finland) are found (**Figure 21**) (Schlusaz et al., 2019).

In 2018, more than 3 million tonnes of fluff pulp were used for the manufacturing of baby diapers and feminine hygiene products (Table 14). As the market for both products is expected to grow so will be the market for fluff pulp (Cavanagh, 2018).

Fluff pulp demand is driven by growth in GDP per capita and by growth in the population segments of potential absorbent hygiene product users where babies, women and senior adults are the main potential consumer groups. In fact, growth is largely driven by demographics while emerging markets are constrained by income, i.e., economic growth is correlated with fluff demand (Cavanagh, 2018).

Figure 21. World capacity of fluff pulp production (2018)



Source: Schlusaz et al., 2019.

Table 14. Global forecast growth for fluff pulp 2023

Product	2018 MMt of fluff pulp	2023 growth
Baby diapers	1.86	1.96 (1.1% per year)
Feminine Hygiene	1.33	1.53 (2.8% per year)

Source: Schlusaz et al., 2019.

The market data for cotton show that the latest USDA report featured a downward revision to global production in 2020/21 (-702,000 bales to 112.6 million) and an upward revision to global production for 2021/22 (+515,000 bales to 119.4 million). Figures for mill-use were increased for both the old and new crop years. The estimate for 2020/21 rose +564,000 bales (to 118.6 million), and the figure for 2021/22 rose +619,000 bales (to 123.2 million). The current projection for global ending stocks generates a global stocks-to-use ratio of 71.2%. This value is above those between 2016/17 to 2018/19, when figures ranged between 66.0% and 69.0%. Apart from those three crop years, however, the current forecast for the ratio would be the lowest during the past decade. The past decade was a period where global stocks shifted markedly higher. During the preceding decade (2001/02 through 2010/11), the global stocks-to-use ratio generally ranged between 40% and 60%. Since 2011/12, the global stocks-to-use ratio has generally ranged between 65% and 95% (Cotton Incorporated, 2021).

An alternative to fossil-based plastic used in AHPs could be a biobased option. Biobased plastics are expected to grow at 4% per year for the next 5 years. Depending on the type of polymer, the EU is either an importer or an exporter. For example, biobased polyethylene is produced exclusively in Brazil from cane sugar. On the other hand, in Europe, the starch industry (250 Kt/year) is well developed and several sites produce polylactic acid or PLA (7 kt/year). PLA is a thermoplastic polyester typically made from fermented plant starch such as from corn, cassava, sugarcane or sugar beet pulp. The EU-27 is often a net importer of biobased products. When net exports were found, they were often very small in quantity. Exceptions are lactic acid (–32 kt/a) and starch used for polymers (–80 kt/a) (Spekreijse et al., 2019).

However, the environmental benefits of substituting materials used in producing AHPs are not clear; e.g., bioplastics may reduce some impacts but increase others. While substituting fossil-based plastics for biobased materials results in environmental benefits in some impact categories, there is potential for burden shifting. The agricultural processes associated with producing biobased materials generally leads to higher land use and water depletion, amongst other impacts, depending on the particular feedstock. Furthermore, the sourcing of biobased materials and the context in which the AHPs are used, in particular whether they are composted at EoL, have important implications for whether the environmental benefits of biobased AHPs are achieved (UNEP, 2021).

Polymers for plastics dominate the total EU production, while, for these, the biobased share is only 0.4% and biobased production is 268 kt/a. It is interesting to observe that cosmetics and personal care products; paints, coatings, inks and dyes; and surfactants have high biobased production volumes, although these product categories are less commonly thought of as being biobased than, for instance, bio-plastics. It is difficult to estimate the exact biobased share of personal care products, as more than 5,000 synthetic and biobased products exist in this category (Spekreijse et al., 2019), however, as AHP market is expected to grow, the same could be thought for the biobased material content of these products.

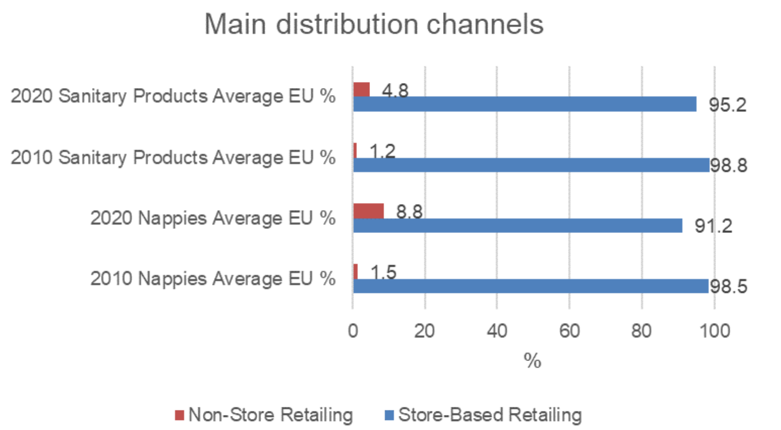
3.6 Consumer-related data for AHPs

The main distribution channels, user behaviour and trends will be analysed within this section.

3.6.1 Distribution channels

Distribution channels are the methods by which companies deliver products and services to customers and end users. Some businesses sell directly to their customers, while others might use a retailer or wholesaler to serve as an intermediary. According to data from Euromonitor International, disposable sanitary products (aggregated data for pads, panty liners and tampons) and baby diapers in the EU are being purchased by customers mostly from store-based retailing. However, from 2010 to 2020, European consumers increased their purchase for both baby diapers and sanitary products from non-store retailing (**Figure 22**). In 2010, baby diapers and sanitary products were mostly acquired (98%) from store-based retailing while in 2020, these values decreased to 91% and 95% for baby diapers and sanitary products, respectively. The first main conclusion to draw from Figure 22 is that non-store purchase is slowly increasing specially in the case of baby diapers.

Figure 22. Main distribution channels for sanitary products and baby diapers in the EU (2010 and 2020)



Source: Euromonitor International: Tissue and Hygiene industry edition 2021.

When looking at the store-based retailing for AHPs, grocery retailers are the main distribution channel while for non-store retailing the e-commerce or online shopping is the most used channel (**Figure 23**). For both, baby diapers and sanitary products, the e-commerce has increased their sales in 2020 with respect to the data for 2010.

Figure 23. (a) Store-based retailing for AHPs in the EU (2010 and 2020) (b) Non-store-based retailing for AHPs in the EU (2010 and 2020)

Source: Euromonitor International: Tissue and Hygiene industry edition 2021.

Table 15 shows the full list of distribution channels for each product type for 2010 and 2020 in Europe excluding data from Cyprus, Luxemburg and Malta. It should be noted that these data concern disposable products. Although non-store based retailers have seen an increment in their sales (mainly e-commerce, selected **bold** in Table 15), hypermarkets and supermarkets (HM/SM) are still the principal channels for acquisition for consumers when it comes to AHPs (selected **bold** in Table 15).

Global trends show that online distribution, HM/SM, drug stores, and convenience stores are the leading channels used by baby cloth diaper manufacturers for sales. Of these, HM/SM will account for a relatively larger share of sales. HM/SM accounted for more than 46% of the market, owing to the higher penetration of these outlets to improved product access for consumers, and robust retail supply chains from suppliers (Fact. MR, 2021).

Regarding reusable period underwear, online stores are the most preferred sales channels and are expected to maintain the lead in the coming years. The expansion of offline sales channels such as exclusive stores and multi-brand stores are expected to boost the growth of the market. However, sales via online channels are slowly catching up. Based on prevailing dynamics and changing consumer preferences FMI has forecasted online channels to rise at 15.8% CAGR through 2020-2030 (Future Market Insights, 2021).

In general, reusable products are most often purchased online, followed by buying in a pharmacy or supermarket (Zero Waste Scotland, 2019).

Table 15. Distribution channels for AHPs in 2010 and 2020 in Europe

Store type (Cyprus, Luxemburg and Malta excluded)	2010 Baby diapers Average EU %	2020 Baby diapers Average EU %	2010 Sanitary Products Average EU %	2020 Sanitary Products Average EU %
Store-Based Retailing	98.5	91.2	98.8	95.2
Grocery Retailers	78.9	73.1	74.4	72.7
Modern Grocery Retailers	73.1	69.8	67.1	67.1
Convenience Stores	4	3.2	3.8	3.8
Discounters	9.3	11.5	9.2	10.8
Forecourt Retailers	0.8	0.6	0.8	0.7
Hypermarkets	**25.2**	**24.1**	**21.2**	**21.4**
Supermarkets	**34.2**	**31.7**	**32.4**	**31.5**
Traditional Grocery Retailers	5.7	3.2	7.3	5.6
Non-Grocery Specialists	18.6	17.2	23.2	21.3
Health and Beauty Specialist Retailers	17.5	16.5	22.3	20.6
Other non-grocery retailer	1.7	1.5	1.5	1.2
Mixed Retailers	2.3	1.5	2.4	2.1
Department Stores	1.7	1.4	1.4	1.3
Mass Merchandisers	1.9	0.8	2	2.5
Variety Stores	1.6	1.3	1.6	1.4
Warehouse Clubs	0	0	0	0
Non-Store Retailing	1.5	8.8	1.2	4.8
Direct Selling	0.4	0.1	0	0.1
Homeshopping	0.1	0	0	0
E-Commerce	**1.5**	**8.9**	**1**	**4.6**
Vending	0.2	0.2	0.6	0.5

Source: Derived from Euromonitor International: Tissue and Hygiene industry edition 2021.

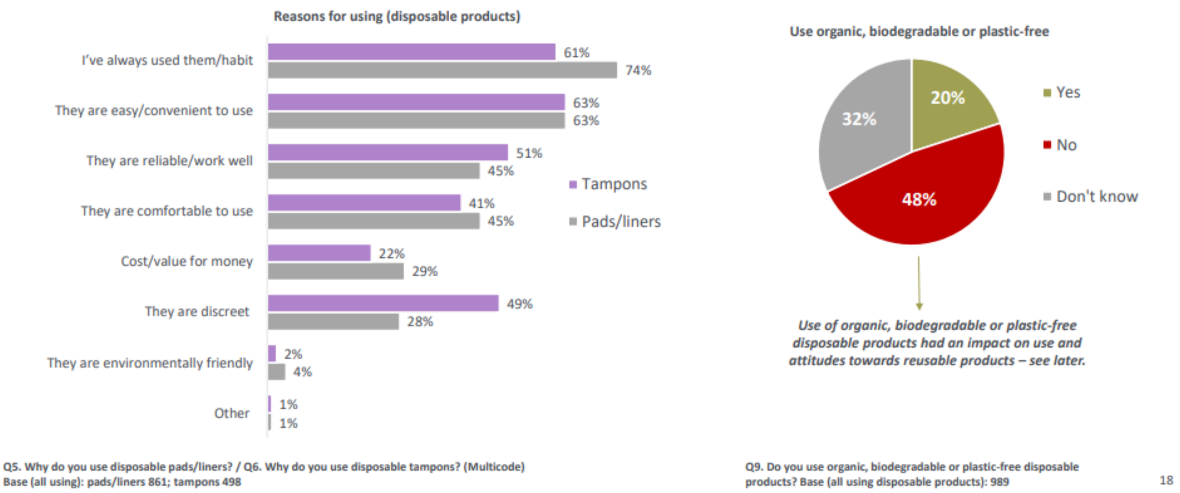
3.6.2 Consumer behaviour

A recent study was carried out in Scotland which aimed to conduct research with consumers on reusable menstrual products. The study was performed as an online survey of 1,015 people across the age-range of 16-55 years-old using menstrual products (data were weighted to be nationally representative). The main outputs showed the following insights (Zero Waste Scotland, 2019). .

- Pads and tampons were the most commonly used disposable products among respondents, whereas menstrual cups were the most used reusable option.

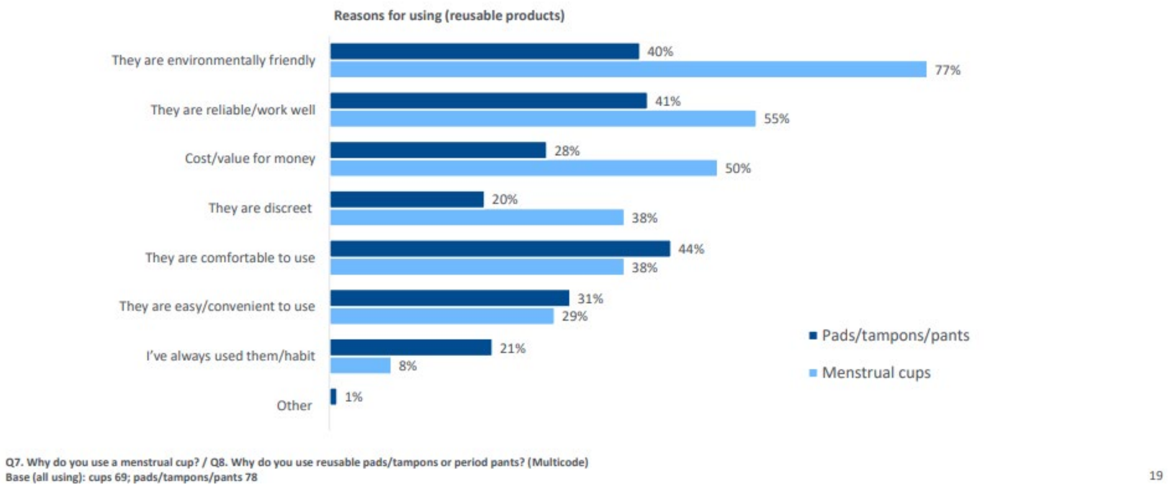
- Social issues seem important, as for example the primary influencers of people's initial period product choice were female relatives. Most participants had used disposable pads for their first periods.
- Effectiveness, convenience and comfort were key factors in choosing products, but most did not consider a wide range of options. In fact, most people (80%) have never tried reusable menstrual products, but one in ten do use them (10%), however of those, just 3% of interviewees use reusable products exclusively.
- Main prompts of product choice were advice from mums, advertising and recommendations from friends. Those currently using reusable products were more likely to mention advertising, recommendations from friends/healthcare professionals and free trials at work.
- Survey results confirm that habits are well ingrained – two thirds of participants had never changed product type. For those who have changed, main drivers were cost/value, environmental concerns, comfort and changes in periods/flow.
- Those who had never tried reusables and were shown descriptions and images of the options were most likely to consider period pants (51%) and least likely to go for reusable tampons (21%).
- Environmental and social/ethical concerns are at the bottom of the list when choosing menstrual products whereas reliability, comfort, hygiene and ease of use are key factors (**Figure 24**).
- The main reasons for using menstrual cups are focused on them being environmentally-friendly, comfortable and a good value for money. Users of the other reusable products tended to mention comfort, followed by environmental reasons and reliability (**Figure 25**).

Figure 24. Main reasons for using disposable menstrual products



Source: Zero Waste Scotland, 2019.

Figure 25. Main reasons for using reusable menstrual products



Source: Zero Waste Scotland, 2019.

Although the mentioned study was performed in Scotland, data could be extrapolated or could serve as a starting point regarding perception and reasons to use reusable options for feminine menstrual care.

Euromonitor International provided results on a survey from 2020 about consumer preference when purchasing baby diapers including information on disposable diapers features and willingness to pay from several countries across the world. In this consumer lifestyle survey, consumers were asked two questions. In the first question, consumers had to answer to which features or attributes they look for when buying disposable diapers for their children. They had to select from a list of 19 attributes all the ones that apply. It was done in the same way for the second question, where consumers were asked about the features for which they would be willing to pay more for when buying disposable diapers for their children. They had to select from the very same list of 19 attributes the ones that would apply to them.

The attributes are summarised in Table 16 while the countries of study were Australia, Brazil, Canada, China, Colombia, France, Germany, India, Indonesia, Italy, Japan, Mexico, Poland, Russia, South Africa, South Korea, Thailand, Turkey, United Arab Emirates, the UK and USA.

Table 16. Summary of questions and attributes from baby diaper survey

Question 1	**Which features or attributes do you look for when buying disposable diapers for (your) children?**	
Question 2	**Which features would you be willing to pay more for when buying disposable diapers for (your) children?**	
Attributes		
Able to buy in bulk	Manufactured locally	Store brand/private label
Biodegradable	Natural ingredients	Strong/well-known brand
Environmentally/ethically conscious	Organic ingredients	Supports a charity or charitable cause
High quality	Premium/luxury brand	Sustainably sourced and produced
Leak protection	Recyclable packaging	Value for money
Low price	Soft materials for baby skin	None of the above
Certified as safe for children by a government or non-profit organization		

Source: Euromonitor International: Voice of the Consumer 2021 Survey 1.

The country with more respondents was Poland, where for question 1 (32 respondents in the range age 30-44), the most voted answer was 'value for money' (47%), followed by 'soft materials for baby skin' (37.5%), 'leak protection' (34.4%). However, 'strong/well-known brand' is still of importance (28.13% of positive answers) and natural ingredients (25%). Recyclable packaging was selected by 18.75% while sustainable sourced and produced was voted by 9.38% of the survey participants. The question 2 was answered by 31 respondents, where the most voted attributed were 'high quality' (32%) and 'leak protection' (25%). 'Biodegradability', 'certification as safe for children by a government or non-profit organization' and 'soft materials for baby skin' were voted by over 22% of respondents.

From these results it can be concluded that the main attributes when purchasing baby diapers are related to 'value for money' and performance as 'leak protection' or 'soft materials' while the consumers were also inclined to pay more for 'high quality' diapers and also 'leak protection'. It is also interesting to observe they would also pay more if the diapers are biodegradable or certified which gives an insight of new market trends.

3.7 Conclusions of the AHP market analysis

The market analysis presented in this report allows for some key conclusions about the products within the scope of this project. While the main messages are summarised in this section, additional information in terms of market segmentation, market developments or other aspects which could be beneficial for the development of EU Ecolabel criteria is also provided.

Market data have been collected mainly from Euromonitor International; however, data on relevant trends have been obtained from several online resources, scientific publications and reports. There is the possibility for real market data to differ sometimes from the information reported here. However, it must be noted that more refined data sources are not available. These pieces of information can be used as a basis for discussing on the market of this product group.

Market penetration of the EU Ecolabel in AHPs

The number of EU Ecolabel licences and products have increased since the previous revision in 2017 (3 licenses for 5 products). As of 2023 there are 18 licenses and 538 licensed products distributed across in 8 countries (Finland, Germany, Spain, Italy, Denmark, France, Sweden and Czech Republic). The general trend indicates a steady growth in both the number of licences awarded and the number of licensed products.

Sales figures

The market analysis for disposable AHPs presents two significantly different pictures depending on whether sales volumes are reported in monetary value (EUR) or units **Figure 8**). In terms of numbers of units sold, children's diapers are more than 35% of the AHP market (sales volume). However, on the basis of value in EUR, the sales volume accounts for nearly 60% of the monetary value in the EU-27 and the UK. This difference is due to the higher unit price of the product itself.

In terms of the functional segmentation of the market of feminine care products, the share of pads or panty liners is greater than the share of tampons. As highlighted before, a decrease in tampons sales volume was observed, mainly in Spain and France. Concern for the environment may be a reason behind this change. However, geographical differences could apply as well.

No data were available regarding the segmentation of baby diapers, pads and panty liner types or applicator and non-applicator tampons. AHP suppliers and manufacturers have indicated that digital tampons (non-applicator tampons) are the most representative of the market.

Regarding the geographical segmentation of AHPs within the EU-27 and the UK, the following key statements can be made:

- As AHPs are generally articles of daily use, there is a good correlation between the population size of each country and the share of AHPs sold in each of the countries.
- Some regional differences on a feminine care products specific level can be identified in Figures 4 to 8 for additional details. In general, Italian women seems to prefer feminine care pads whereas the German or British women purchase relatively more tampons.

Imports/exports

Analysis of the export / import data did not provide more conclusive information than the fact that exports are higher than imports for all the years studied. Both exports and imports tended to increase in recent years, with the value of imports having increased slightly. It has been noticed that in 2019, a stronger increment also occurred to the production of AHPs. Data were obtained from the PRODCOM categories 17.22.12.10, 17.22.12.20 and 17.22.12.60[23].

Key actors and brands

When looking at the worldwide key companies and brands for AHPs, P&G has the largest market share, with Pampers being the most common brand for baby diapers (2011 and 2020 data). The second brand worldwide is Huggies (from Kimberly- Clark Corporation). It is worth noting that the majority of the key AHP players are headquartered outside Europe.

Distribution channels

Regarding distribution channels, although non-store based retailers (online purchase mainly) have seen an increment in their sales from 2010 to 2020, hypermarkets and supermarkets (store-based, modern grocery retailers) are still the principal channels for acquisition for consumers when it comes to (disposable) AHPs.

Forecasts for disposable and reusable

The disposable baby diapers market exhibits a rising trend as is the case for disposable feminine care products. In the same way, reusable product demand is also growing, however it seems reusable products will not reach the market share of disposable AHPs anytime soon.

It has been noticed that menstrual cups have the highest CAGR predicted during 2020–2027 while period underwear could experience a superior CAGR through the end of 2030. Differences in the way both products are used may explain this trend: while several period underwear pieces are needed per cycle, only one menstrual cup is used for the whole cycle. Furthermore, durability may play an important role: menstrual cups can be used for up to ten years while period underwear have a shorter lifetime. Germany is the second largest period underwear market in Europe followed by favourable government policies whereas demand is increasing in Italy and France mainly.

Regarding consumer perception and willingness to shift from disposable to reusable, available public surveys for feminine care products have shown that although pads and tampons are the most commonly used disposable products, menstrual cups are the most used reusable option. Environmental and social/ethical concerns are at the bottom of the list when choosing menstrual products as reliability or comfort are primed. However, the main reasons for using menstrual cups are focused on them being environmentally-friendly, comfortable and a good value for money as they can be used for five to ten years depending on the brand.

A survey on consumer perception about willingness features for baby diapers, show the main attributes are related to 'value for money' and performance as 'leak protection' or 'soft materials for the baby skin'. Biodegradability and certification are both stated as in the top five features from consumer willingness to pay more for these products.

Materials used for the manufacture of AHPs as SAP, fluff pulp or bio-materials

SAPs have a fossil origin and since global petroleum prices may have decreased from 2021 onwards, SAPs prices used for disposable AHPs may also decrease forcing the prices of final products to also suffer a decrement. Fluff pulp also used primarily in AHPs seems to have a growing demand as AHPs are influenced by GDP per capita and population. As the use of biobased plastics is expected to grow in general, their use in AHPs could suffer the same trend. Although no actual indicators are sufficient up-to-date to confirm this material substitution will be the case. Europe is a leading player on the starch industry where PLA is produced. Being difficult to predict, as AHP market is expected to grow, the same could be thought for the biobased material content of them. However as environmental benefits of substituting materials are not so clear, other innovations could be expected.

[23] PRODCOM categories: 17.22.12.10 - Sanitary towels and tampons, napkins and napkin liners for babies and similar sanitary articles, of wadding, 17.22.12.20 - Sanitary towels, tampons and similar articles of paper pulp, paper, cellulose wadding or webs of cellulose fibres and 17.22.12.60 - Sanitary towels (pads), tampons and similar articles, of other textile materials (excl. of wadding of textile materials).

Final insights

On the basis of the gathered information, it can be concluded that the market share of disposable Absorbent Hygiene Products is high and it keeps growing exponentially. Therefore, the potential environmental benefits of the European Ecolabel addressing the disposable AHP is much larger and can help addressing the EoL impacts they create.

The essential nature of AHP appears to have allowed sales to be unaffected by the COVID-19 crisis, although some disruptions may have been found throughout the supply chain and material sourcing on the manufacturing side.

Regarding reusable options, at this point, there is not a complete set of market data for reusable AHP alternatives. Solid information was found on baby diapers, where these represent a very marginal part of the market as opposed to their disposable counterparts. The reusable menstrual cup and period underwear show a growing market trend although some sources claim that it remains a fringe product. The estimation of reusable menstrual cloth pads sold in Europe is quite difficult as most of them are produced by small manufacturers.

Lastly, no substantial market data were found for cloth and disposable breast pads. Thus, the market share of non-disposable feminine care products versus disposable ones could not be compared in-depth. However, based on the information presented in this document, it can be assumed that in both cases, the market share is very low.

4 Task 3: Technical analysis

The aim of Task 3 is to provide specific technical support and information on environmental, health and technical issues related to the products considered in the scope extension (selected in section 2.7) in order to revise the existing EU Ecolabel criteria.

The analysis addresses the information available in Environmental Product Declarations (section 4.1), the presence in AHPs of chemicals of potential concern in terms of environmental and human hazard (section 4.2), and the main production processes as well as examples of innovation and best practices in the market (section 4.3). Task 3 also includes information on the environmental impacts of absorbent hygiene products throughout their life-cycle (section 4.4), gathered via a literature review of life cycle assessments (LCA) available in the literature (section 4.4.1) and via a screening LCA study produced as part of this project (section 4.4.3).

Task 3 concludes presenting the results of the preliminary questionnaire to stakeholders on the validity of the criteria set and an overview of the relevant areas of the current criteria set that should be taken into account for the revision (section 4.5).

4.1 Review of information in Environmental Product Declarations

The Environmental Product Declarations (EPD) are based on ISO standards and are therefore internationally harmonised. EPDs offer the relevant basic data on the environmental properties of a product for sales and marketing purposes.

There are recent Product Category Rules (PCR) developed in the framework of the International EPD System for Absorbent Hygiene Products (EPD System, 2021). The category consists of the following three groups of absorbent hygiene products: baby diapers, feminine sanitary protection and adult incontinence care products. This PCR was developed in order to enable publication of Environmental Product Declarations (EPD) for this product category based on ISO 14025, ISO 14040/14044 and other relevant standards to be used in different applications and among target audiences.

The International EPD system follows the United Nations Central Product Classifications (UN CPCs). Each EPD must state which CPC code the product falls under. The most relevant codes and categorisation for Absorbent Hygiene Products are as follows:

Section 3: Other transportable goods, except metal products, machinery and equipment

Division 32: Pulp, paper and paper products; printed matter and related articles

Group 321: Pulp, paper and paperboard

Class: 3219: Other paper and paperboard products

Subclass 32193: Toilet paper, handkerchiefs, towels, serviettes, napkins for babies, tampons, and similar household, sanitary or hospital articles, and articles of apparel, of paper pulp, paper, cellulose wadding or webs of cellulose fibres.

4.2 Chemicals of concern in AHPs

When current EU Ecolabel criteria for Absorbent Hygiene Products were voted it was requested that, for the next revision, the Commission shall further investigate the pros and cons of using lotions and fragrances in this product group and consider the need for the use of any antimicrobial agent in AHPs, as follows:

a) Isothiazolinones: Scientific evidence needs to be investigated on the use/effect of isothiazolinones in leave-on products with the purpose of further restrictions in lotions (Policy Brief, 2020).

b) Lotions, fragrances and antimicrobial agents: Investigations need to be done regarding the use of lotions and fragrances in this product group, as well as of antimicrobial agents.

4.2.1 Biocides

4.2.1.1 Isothiazolinone biocides

Biocide is a chemical and/or biological substance that destroys, deters, renders harmless, or exerts a controlling effect on any harmful organism. There have been increasing concerns regarding hidden environmental/health risks of pervasive and perpetual exposure to biocides that could occur during and after use of consumer products containing biocides. Biocides are known to be contact allergens, to cause skin irritation and inhalation toxicity (Ju Heo et al., 2018).

Isothiazolinones are widely used as preservatives or biocides in household and industrial products, with several of them contained in cosmetic products and detergents. Their wide use in cosmetics is because of their effectiveness at a broad spectrum of pH even at low concentrations. Isothiazolinone biocides are strong sensitisers, producing skin irritations and allergies, and may cause ecotoxicological hazards. Therefore, their use is restricted by EU legislation (Silva et al., 2020).

The Biocidal Products Regulation (BPR, Regulation (EU) 528/2012)[24] concerns the placing on the market and use of biocidal products, which are used to protect humans, animals, materials, or articles against harmful organisms such as pests or bacteria, by the action of the active substances contained in the biocidal product. All biocidal products require an authorisation before they can be placed on the market, and the active substances contained in that biocidal product must be previously approved. The use of the isothiazolinones addressed in the next sections (MIT, BIT and CMIT) as a biocide in the EEA and/or Switzerland for product preservation is under review[25]. The Cosmetic Products Regulation[26] prohibits MIT and the formulation CMIT/MIT in a 3:1 ratio in leave-on products (as no safe concentration is possible), while limiting their presence at 15 ppm (0.0015 %) in rinse-off cosmetic products.

Widely used isothiazolinones are chloromethylisothiazolinone (CMIT[27], CAS 26172-55-4; 5-chloro-2-methyl-4-isothiazolin-3-one) and methylisothiazolinone (MIT[28], CAS 2682-20-4; 2-methyl-4-isothiazolin-3-one), which is a powerful biocide. According to the harmonised classification and labelling, MIT is a Category 1 skin sensitiser (H317). CMIT does not have a harmonised classification; however, ECHA received 456 notifications of its hazardousness as a Category 1 skin sensitiser (H317).

In the previous criteria development, a preliminary screening of chemicals found nanosilver to be the only biocide used in AHPs (nanosilver is banned according to current EU Ecolabel criteria in force). However, the Belgian Federal Public Service Health, Food Chain Safety and Environment (VITO, 2018) has detected compounds of MIT (CAS 2682-20-4; 2-methyl-4-isothiazolin-3-one) and CMIT (CAS 26172-55-4; 5-chloro-2-methyl-4-isothiazolin-3-one) in samples of a tampon and a sanitary pad, respectively.

4.2.1.2 Antimicrobial agents

There are more than 250 commercially known antimicrobial agents available in the market. In particular, there is an observable significant increase of the demand for antimicrobial finishes and additives in the baby diaper on the global market (Uddin, 2014). When it comes to sanitary napkins, it is claimed that, in order to prevent infections, the fabrics should have antimicrobial activity (Shibly et al., 2019).

One example of antimicrobial agents used in AHPs is nanosilver, which is banned in current EU Ecolabel criteria due to some indications suggesting the risk of promoting the antibiotic resistance of bacteria, and the potential hazards associated with the use of silver particles. Triclosan (TCS) is not allowed either, and since 2017 its use has been banned in the EU from all human hygiene biocidal products[29]. However, its congener

[24] Regulation (EU) No 528/2012 of the European Parliament and of the Council concerning the making available on the market and use of biocidal products.
[25] MIT (methylisothiazolinone) https://echa.europa.eu/it/substance-information/-/substanceinfo/100.018.399
CMIT (chloromethylisothiazolinone) https://echa.europa.eu/it/substance-information/-/substanceinfo/100.043.167
BIT (benzisothiazolinone) https://echa.europa.eu/it/substance-information/-/substanceinfo/100.018.292
[26] Regulation (EC) No 1223/2009 of the European Parliament and of the Council of 30 November 2009 on cosmetic products.
[27] Echa Infocard for CMIT100.043.167
[28] Echa Infocard for MIT 100.018.399
[29] Commission Implementing Decision (EU) 2016/110 of 27 January 2016 not approving triclosan as an existing active substance for use in biocidal products for product-type 1, OJ L 21, 28.1.2016, p. 86–87.

triclocarban (TCC) is an antibacterial agent used in feminine care products (sanitary pads, panty liners, and tampons) (Gao and Kannan, 2020), which has been claimed to have endocrine-disrupting properties (Iacopetta et al., 2021). Due to its toxicity, the US Food and Drug Administration banned its use in hand and body washes in September 2016. Nonetheless, the transfer rates of TCC from feminine care products are not known (Gao and Kannan, 2020). TCC is on the CoRAP[30] (Community rolling action plan) list, and it was evaluated for concerns over it being suspected of being reprotoxic, a potential endocrine disruptor, and of wide dispersive use[31]. The evaluation concluded in November 2020 that more data were necessary in order to clearly conclude on TCC's effects. However, industries have declared a stop in the manufacture just before and during the evaluation of the substance. Consequently, there is no active registration of triclocarban in the EU[32].

Synthetic antimicrobial agents are linked with side effects as well as harmful effects on the environment (Mor et al., 2015). Unfortunately, the release of these antimicrobial agents from the finished fibrous article into the environment has not been sufficiently researched yet (Uddin, 2014). A recent study states that '*TCC can accumulate in the roots of plants grown in biosolids-amended soils and earthworms living in treated soils, indicating the potential ecological risk. TCC has been detected in biosolids from wastewater treatment, and its ability to persist in agricultural soils after the land-application of biosolids, has been demonstrated, with an estimated half-life of 191 days' (*Iacopetta et al., 2021).

A recent review highlights the application of principal antibacterial agents such as quaternary ammonium compounds, N-halamines, chitosan, polybiguanides and bioactive plant-based products on fabrics. The chitosan treatment on cotton fabrics imparts antibacterial activity against *S. aureus* and *E. coli*. It should be mentioned that synthetic fabrics, such as polyester, polyamide, and acrylic, can also be made antimicrobial by treating them with antimicrobial agents (Rajendran et al., 2016).

Several studies point out that bioactive substances present in herbal extracts have an antibacterial effect on fibres which helps to reduce the growth of microbes. Natural herbal extract finishes on fabrics are claimed to have many benefits, such as being non-toxic, non-irritant, biodegradable, cost-effective and easy availability (Zaghloul et al., 2017; Lalitha et al., 2014; and Uddin 2014). In baby diapers, Mor et al. (2015) report ZnO nanoparticles induced in the baby diapers as a non-toxic solution to reduce the chances of skin problems, but conclude that curcumin and neem powder are the best antimicrobial agents. Unfortunately, information on the commercial use and application of herbal extracts as antimicrobial agents in Absorbent Hygiene Products has not been found at his stage.

4.2.2 Fragrance compounds in feminine care products and associated risks

Fragrances have an essential role in AHPs, masking bad odours. Scented versions of the feminine care pad contain a small amount of perfume applied between the backsheet and the subsurface of the core (Woeller and Hochwalt, 2015).

The overall composition of fragrances includes volatile organic compounds (VOCs) such as styrene (CAS 100-42-5), chloromethane (CAS 74-87-3), chloroethane (CAS 75-00-3), chloroform (67-66-3), acetone, phthalates, dioxins, dioxin-like compounds, furans, and methyldibromo glutaronitrile (MDBGN) (Woo et al., 2019). Other substances usually cited in scientific literature that are found in AHP fragrances are aromatic compounds such as xylene, essential oils (terpenes, limonene, linalool, citronellal, geraniol, hydroxycitronellal, hexyl cinnamal), and benzyl salicylate (CAS 118-58-1) (Pastor-Nieto and Gatica-Ortega, 2021). Some of these substances have been found in sanitary pads in concentrations below 0.1 ppm (VITO, 2018). The Belgian Federal Public Service Health, Food Chain Safety and Environment quantitative analysis adds evidence to such findings with a number of samples done on tampons and sanitary pads (VITO, 2018).

For more than 40 years, the fragrance industry has examined ingredients used in personal care products to ensure the safe use of fragrances. IFRA standards – mandatory for all IFRA members – ban, limit or set criteria for the use of certain ingredients, based on the latest scientific evidence and consumer insights. Nevertheless, concerns have been raised linking perfumes applied on AHPs and allergic contact dermatitis (Desmedt et al., 2020). Additionally, some fragrances are known to be CMR substances (carcinogens, mutagens, and toxic to reproduction), thus classified with H341, H351, or H360. Respiratory, endocrine and

[30] https://echa.europa.eu/regulations/reach/evaluation/substance-evaluation/community-rolling-action-plan

[31] https://echa.europa.eu/it/information-on-chemicals/evaluation/community-rolling-action-plan/corap-table/-/dislist/details/0b0236e1820e17bb

[32] https://echa.europa.eu/documents/10162/ed5ddbf6-6890-0a3b-f479-3d8496fa5d10

neurological effects have also been discussed in scientific literature. Essential oils can impair the central nervous system, kidney, and respiratory ducts (Pastor-Nieto and Gatica-Ortega, 2021). Moreover, authors such as Gao and Kannan (2020) call for *'further studies determining transdermal absorption rates of chemicals by vaginal mucosa and vulva as well as transfer rates of chemicals from products (under various real-world scenarios)'.* Given all these facts, it does not seem possible to give a full picture of the long-term effects that fragrances present in feminine care pads may be having on the health of women. As a result, action has been taken on different fronts to limit their use. For instance, the French Expert Committee (CES) recommends eliminating the use of all fragrances in the composition of feminine hygiene products, particularly those with irritant and skin-sensitising effects (ANSES, 2018). The Ecolabels Nordic Swan and Blue Angel for Absorbent Hygiene Products already restrict the use of fragrances too. The Nordic Swan does not allow the addition of fragrances or other scents (e.g. essential oils and plant extracts) to the sanitary product, the additional component (individual wrapping) or to any constituent materials/components of the final product. The Blue Angel prohibits fragrances and odour absorbers in the products awarded with the environmental label.

A model for dermal sensitisation quantitative risk assessment (QRA) has been developed and implemented by the fragrance industry. The Scientific Committee on Consumer Safety (SCCS) concluded that: '*The data provided show that the application of the dermal sensitisation QRA approach would allow increased exposures to allergens already known to cause allergic contact dermatitis in consumers. The model has not been validated and no strategy of validation has been suggested*'. There is no confidence that the levels of skin sensitisers identified by the dermal sensitisation QRA are safe for the consumer, and that: '*Identification of safe levels of exposure to existing substances known to cause allergic contact dermatitis in the consumer should be based on clinical data and/or elicitation low-effect levels. Currently, these are the only methods which have proven efficient in reducing/preventing existing problems of sensitisation/allergic contact dermatitis in the consumer*' (Scientific Committee on Consumer Safety, 2011).

Ecotoxicological relevance of fragrances

There is a lack of scientific evidence on environmental pollution associated with fragrance compounds. Some chemically synthetised pure fragrances are of ecotoxicological relevance. Karanal (5-sec-butyl-2-(2,4-dimethylcyclohex-3-en-1-yl)-5-methyl-1,3-dioxane has potential for bioaccumulation. Terpenes react with ozone to form hydroxyl radicals which rapidly react with other organics forming other air pollutants (including hydrogen peroxide in small quantities) with undetermined toxicities. Reaction of limonene with ozone forms small quantities of formaldehyde (Pastor-Nieto and Gatica-Ortega, 2021).

4.2.3 Lotions in baby diapers

Diaper rash dermatitis refers to a group of skin disorders characterised by acute inflammatory reaction on the diaper-covered area caused by physical, chemical, enzymatic, and microbial agents (Sharifi-Heris et al., 2018). The global prevalence of diaper rash dermatitis is between 7% and 35% of its users, and even up to 50% in some studies (Sharifi-Heris et al., 2018). Currently, the treatments for diaper rash mainly include the use of disposable diapers with breathable materials and lotions (Yuan et al., 2018).

Lotion in modern disposable diapers is typically a barrier ointment containing pharmaceutical-grade petrolatum or vaseline, stearyl alcohol, and aloe vera. In some cases, less than one tenth of a gram of petrolatum is included on the newborn diaper top-sheet. Ointment-containing diapers have been clinically proven to reduce skin wetness, improve skin barrier properties, help reduce erythema, and maintain babies' overall skin health. Stearyl alcohol is another ingredient commonly found in the lotions present in disposable diapers (Counts et al., 2017). Nonetheless, the Nordic Swan for Sanitary Products (Nordic Swan, 2021) notes that allergens and carcinogens can occur in lotion preparations. Moreover, in newborns, the increase of absorption of drugs should be taken into account (Sharifi-Heris et al., 2018). As a result, together with Blue Angel, the two ecolabels also restrict lotions on the basis of not being necessary for the absorbent function of the sanitary products.

4.2.4 Test methods

4.2.4.1 EDANA Stewardship Programme CODEX™

The Stewardship Programme CODEX™ for Absorbent Hygiene Products[33] is constituted by four main elements. The first element is a list (the 'Codex') of substances potentially present as impurities at trace levels in Absorbent Hygiene Products. The list is accompanied by guidance limit values that should not be exceeded (second element). The third element consists of standardised test methods to assess the presence and limit values of the substances included in the Codex. The fourth element is an Exposure-Based Risk Assessment (EBRA). **Table 17** gives an overview of the guidance values.

This EDANA Stewardship Programme is open to any company manufacturing and/or placing absorbent hygiene products on the European market. Adhering companies actively commit, among other things, not to exceed the recommended guidance values of trace impurities and to use EDANA-harmonised test methods.

List and limit values

The list of trace impurities covers chemical substances that are not intentionally used to manufacture absorbent hygiene products (AHPs) but that may be present in trace amounts.

Chemicals or classes of chemicals involved include PAHs (polycyclic aromatic hydrocarbon), PCBs (Polychlorinated biphenyls), dioxins, furans, phthalates and formaldehyde.

[33] https://www.edana.org/how-we-take-action/edana-stewardship-programme-for-absorbent-hygiene-products/the-edana-absorbent-hygiene-product-stewardship-programme-codex and https://www.edana.org/docs/default-source/edana-product-stewardship-for-absorbent-hygiene-products/2021-07-06-the-trace-chemical-mill-method-flyer.pdf?sfvrsn=90775ffd_4

Table 17. Limit values which the listed trace impurities should not exceed in Absorbent Hygiene Products (version November 2020)

	Dioxin and Dioxin-like Furans and Polychlorinated Biphenyls		**PAHs**	**Phenols**	**Phthalates**	**Pesticides**	**Organotins**	**Formaldehyde**	**Metals**
Dermal penetration based on dermal absorption estimates and toxicity profiles of the substance**	+		60-10%			<10-1%	<1-<0.011%		—
Trace chemicals	Dibenzo-p-dioxins (PCDDs): 2,3,7,8-TCDD 1,2,3,7,8-PeCDD 1,2,3,4,7,8-HxCDD 1,2,3,6,7,8-HxCDD 1,2,3,7,8,9-HxCDD 1,2,3,4,6,7,8-HpCDD OCDD Dibenzofurans (PCDFs): 2,3,7,8-TCDF 1,2,3,7,8-PeCDF 2,3,4,7,8- PeCDF 1,2,3,4,7,8-HxCDF 1,2,3,6,7,8-HxCDF 1,2,3,7,8,9-HxCDF 2,3,4,6,7,8-HxCDF 1,2,3,4,6,7,8-HpCDF 1,2,3,4,7,8,9-HpCDF OCDF	DLPCBs: Non-ortho PCBs: PCB 77 PCB 81 PCB 126 PCB 169 Mono-ortho PCBs: PCB 105 PCB 114 PCB 118 PCB 123 PCB 156 PCB 157 PCB 167 PCB 189 Hexachlorobenzene	Benzo(a)anthracene Benzo(a)pyrene Benzo(e)pyrene Chrysene Benzo(b)fluoranthene Benzo(k)fluoranthene Dibenzo(a,h)anthracene Benzo(j)fluoranthene Benzo(g,h,i)perylene Indeno(1,2,3,cd)pyrene Phenanthrene Pyrene Anthracene Fluoranthene Naphthalene	Bisphenol A Nonylphenol-di-ethoxylate Nonylphenol	DINP DEHP DNOP DIDP BBP DBP DIBP DIHP BMEP DIPP DnPP DnHP	Glyphosate AMPA Quintozene	Monobutyltin Dibutyltin Tributyltin Triphenyltin Dioctyltin Monooctyltin	Total	Antimony Cadmium Chromium Lead Mercury
Proposed reference value/ Regulatory reference	2ng/kg sum TEQ of the detected congeners of PCDDs, PCDFs and DLPCBs		0.2 mg/kg (PAHs)	0.02% (BPA) 10 mg/kg (Nonylphenol and Nonylphenol-di-ethoxylate)	0.01%	0.5 mg/kg	2 ppb (TBT) 10ppb (other organotins)	16 mg/kg	Sb: 30 mg/kg Cd: 0.1 mg/kg

	Dioxin and Dioxin-like Furans and Polychlorinated Biphenyls	PAHs	Phenols	Phthalates	Pesticides	Organotins	Formaldehyde	Metals
Dermal penetration based on dermal absorption estimates and toxicity profiles of the substance**	+	60-10%			<10-1%	<1-<0.011%		—
								Cr: 1 mg/kg Pb: 0.2 mg/kg Hg: 0.02 mg/kg
Analytical method	Reference value adapted from Regulation EC 1259/2011 on contaminants on foodstuff (infant food) taking into account that the systemic exposure via skin uptake is likely 10% of the oral exposure	Recommendation BfR/German BauA AfPs	Reach Annex XVII entry 66 Oeko-Tex-Standard 100 (Annex 4)	Oeko-Tex-Standard 100 (Annex 6)	Oeko-Tex-Standard 100 (Annex 4 & 6)	EDANA guidelines	Oeko-Tex-Standard 100 (Annex 4 & 6)	Sb: 30 mg/kg Cd: 0.1 mg/kg Cr: 1 mg/kg Pb: 0.2 mg/kg Hg: 0.02 mg/kg Oeko-Tex-Standard 100 (Annex 4 & 6)
**** The dermal penetration classification is in general and specific values would apply where data exist.**								

Source: Adapted from EDANA (2020). Stewardship Programme for Absorbent Hygiene Products. The Codex Document. Link: https://www.edana.org/how-we-take-action/edana-stewardship-programme-for-absorbent-hygiene-products/the-edana-absorbent-hygiene-product-stewardship-programme-codex/trace

Standardised test methods

In order to check compliance with the Codex, measurement tests are needed. Until recently, manufacturers relied on one of two testing strategies for AHP:

I. **Harsh Extraction Method** – using an organic solvent. It provides intrinsic quantification and is still useful for long-term monitoring and studies on single materials. Negatives for this method include the risk of feeding the 'LOQ race', and it does not reflect real-life usage.

II. **ANSES/SCL methods (2.2)** – using urine simulant extraction. Negatives for this method include the fact it is only used by the authorities in France. There is also a risk of overestimation without a correction factor (e.g. real Reflux), there is no standardised simulating pressure, and it can provide few achievable LOQs. Finally, it can only be practically used for size-three diapers.

Alternatively, industry self-develops test methods for the substances for which there are no standardised test methods.

In their Stewardship Programme CODEX™, EDANA developed a methodology with the aim to have an industry-wide harmonised approach that is relatively easy to adopt, robust (repeatable and reproducible), and reflects consumer-relevant aspects. In total, three test methods were developed.

These test methods check that the presence of selected impurities in a product are below the guidance values. These test methods feature experimental extraction/exposure settings that are geared to real-life usage conditions and address the respective sample preparation in detail.

In November 2020, EDANA, the nonwoven industry association, released the EDANA Method NWSP360 series, a practical, robust, repeatable and reproducible test method (EDANA, 2020).

4.2.4.2 Testing on menstrual cups

Tests for biocompatibility

The International Organization for Standardization developed a standard for biological evaluation of medical devices (ISO 10993:2009). The scope of this multi-part standard is to evaluate the effects of medical device materials on the body. Most of the parts of the ISO 10993 standard series discuss appropriate methods to conduct biological tests that may be identified when following Part 1 of the standard.

Even though menstrual cups are not medical devices, several menstrual cup manufacturers decide to carry out tests according to some parts of ISO 10993. One of the main reasons for taking this decision is to guarantee additional safety to their customers. Checking the approach to biocompatibility evaluation used by ISO 10993-1 would be a starting point to determine which biological tests could be more relevant for menstrual cups. The material(s), the device in its final finished form, and possible leachable chemicals or degradation products should be considered for their relevance to the overall biocompatibility evaluation of the device. Endpoints relevant to the biocompatibility evaluation should take into account the nature, degree, frequency, duration, and conditions of exposure of the device materials to the body. The matrix (**Table 18**) is only a framework for the selection of endpoints for consideration and not a checklist of required biocompatibility testing. Some of the endpoints in this table (chronic toxicity, carcinogenicity, reproductive/developmental toxicity and degradation) are not included as separate columns in Annex A to ISO 10993-1:2009, but were included in previous revisions of ISO 10993-1. In addition, a column for material-mediated pyrogenicity, which is included as a subset of acute systemic toxicity in ISO 10993-1:2009, was added in the matrix.

Table 18. ISO 10993-1 and FDA-modified matrix for the selection of biocompatibility endpoints for consideration

Medical device categorisation by			**Biological effect**												
Nature of body contact		Contact duration A- Limited (<24h) B- Prolonged (>24-30 d) C- Permanent (>30 d)	Cytotoxicity	Sensitisation	Irritation or intracutaneous reactivity	Acute systematic toxicity	Material-mediated pyrogenicity	Subacute/ subchronic toxicity	Genotoxicity	Implantation	Hemocompatibility	Chronic toxicity	Carcinogenicity	Reproductive/ Developmental toxicity	Degradation
Category	Contact														
Surface device		A	X	X	X										
	Intact skin	B	X	X	X										
		C	X	X	X										
	Mucosal membrane	A	X	X	X										
		B	X	X	X	o	o	o		o					
		C	X	X	X	o	o	X	X	o		o			

Source: Adapted from FDA, 2020.

Since the contact duration of menstrual cups with the mucosal membrane is time-limited (A), tests for some or all of the following effects may be recommended: cytotoxicity (ISO 10993-5), sensitisation and irritation (ISO 10993-23:2021) or intracutaneous reactivity (ISO 10993-10). It shall be noted that the new versions for Parts 23 and 10 now include testing that does not require animal testing, which is new in this field. Since menstrual cups are consumer products and under European Law cannot be subject to animal testing, the use of only Part 10 (ISO 10993-10) and Part 23 (ISO 10993-23:2021) of ISO 10993 may be recommended. Another issue that should not be overlooked is the "environment" in which a menstrual cup is placed. While the cup will be surrounded by mucosal membrane, this can probably not be compared with devices that are also in contact with mucosal membrane since the pH in the mouth and the vaginal tract is not the same. Therefore, the testing set-up has to be carefully considered.

As mentioned earlier, menstrual cups are not required to be manufactured from medical-grade materials. Moreover, the term "medical-grade" silicone[34] has no official definition. However, some menstrual cup manufacturers are aware of the sensitive application the menstrual cups have, and decide to produce their menstrual cups with medical-grade materials. As a result, some chemical providers offer silicone raw materials for medical applications, which were tested according to selected tests of the ISO 10993 standard but also the USP Class VI standard. USP Class VI is a designation from the U.S. Pharmacopeia, which refers to a panel of tests that are used to determine the biological reactivity of the silicone in vivo. There are other USP classes as well, but USP Class VI is the strictest. There is not a designation for Europe. However, some of the tests included in the ISO 10993 series seem to be very similar.

According to silicone manufacturers, the USP Class VI standard (acute systemic and intracutaneous toxicity and implantation tests) and the ISO 10993 standard (cytotoxicity, pyrogenicity and sensitisation tests) are the most commonly used standards in sensitive applications, also for non-medical devices. It shall be noted that there are no equivalent requirements to the USP Class VI in the European Pharmacopeia.

[34] "Medical-grade" silicones are silicones tested according to relevant biocompatibility criteria and showing no adverse effects in these criteria.

Some menstrual cups that are produced and sold in Europe publicly announce their compliance with one or more of the abovementioned standards: the LUNACUP evolution menstrual cup is made of medical-grade silicone which complies with the American USP Class VI certification as well as EN-ISO 10993 (Luna Cup, 2020).

Louloucup is made in France in a factory authorised to produce medical articles in accordance with ISO 13485:2016 standards (Loulou cup, 2021). The silicone is tested according to ISO 10993- 6-10 and USP Class VI. Clariphram cups also made in France follow EN-ISO 13485:2016 (Clariphram cup, 2021).

On a different note, the first ISO standards on sex toys will be published in the coming months. Sex toys are also consumer products in the eyes of EU legislation, as is the case of menstrual cups. Moreover, some of them are silicone-based products and in this standard it has already been decided to require biocompatibility testing, recommending the ISO 10993-series.

Tests to determine chemical presence in menstrual cups

According to information collected from silicone suppliers and previous analysis, reusable menstrual cups can be used safely.

In 2018, KEMI, the Swedish Chemicals Agency, analysed the presence of chemicals in different types of menstrual cups purchased on the Swedish market and on the Internet (KEMI, 2018). Seven substances out of eight that were analysed quantitatively were reported to be above the reporting limit defined in the study. The TPE menstrual cups (references 3 and 4 in **Table 19**) did not contain any of the analysed substances.

Table 19. Substances analysed in menstrual cups by KEMI (Swedish Chemicals Agency)

Substance (CAS)	References								Reporting limit (RL)*
	1	2	3	4	5	6	7	8	
Composition	Silicone		TPE		Silicone				
Benzophenone (119-61-9)	-	-	-	-	-	-	-	740-750	10
Decamethylcyclopentasiloxane (D5) (541-02-6)	1.5-1.6	2.0-2.0	-	-	1.8-1.8	3.7-4.0	740-740	1.6-1.6	1
Decamethylcyclononasiloxane (D9) (556-71-8)	76-80	160-170	-	-	5.6-5.7	57-60	740-760	12.0-12.0	1
Decamethylcyclohexasiloxane (D6) (540-97-6)	8.5-8.8	1.7-1.7	-	-	2.2-2.2	5.6-5.8	1900-2000	2.8-2.9	1
Hexadecamethylcyclooctasiloxane (D8) (556-68-3)	33-35	47-50	-	-	2.6-2.8	26-27	-	5.8-6.1	1
Octamethylcyclotetrasiloxane (D4) (556-67-2)	<RL	<RL	-	-	<RL	<RL	88-89	<RL	1
Tretradecamethylcycloheptasiloxane (D7) (107-50-6)	23-23	7.7-8	-	-	2.3-2.5	15-15	-	4.9-4.9	1

Source: Adapted from Swedish Chemicals Agency, 2018.

NB: <RL*: Less than the reporting limit. -: Not analysed because no indication of the presence of these substances during screening. RL*: The lowest concentration of a substance that can be measured with reasonable statistical certainty in chemical analysis.*

In 2015, the Swiss consumer association *A Bon Entendeur* published a study on sanitary napkins, tampons and menstrual cups, one of the objectives of which was to test for the presence of certain chemical compounds: formaldehyde and perfumes. Among the three menstrual cups tested, only one contained traces of formaldehyde (*A Bon Entendeur, 2015)*.

In 2018, the Danish Consumer Council THINK Chemicals analysed seven menstrual cups to determine if they contained chemicals such as phthalates, nitrosamines, PAHs, heavy metals, chlorinated paraffins, latex proteins or added substances. Six of the tested products were silicone and one was made of TPE. The VOC emission level was analysed only for silicone menstrual cups. The tests revealed the presence of traces of DEP (Diethyl phthalate), PAHs (naphthalene in two references) and latex, in one, three, and two analysed products, respectively. Five out of six analysed silicone menstrual cups released VOCs (Danish Consumer Council THINK Chemicals, 2018).

In 2019, the French association '60 million consumers' tested four types of medical-grade silicone menstrual cups. Of these, three were manufactured using Pt as the catalyst for the silicone. Substances such as bisphenol A, S and F, phthalates, PAHs and azodyes (in the coloured one) were analysed in the menstrual cups. The presence of these substances was not found in any of the four menstrual cups tested whether or not they were sterilised before use (60 million consumers, 2019).

Also, in 2019, the French SCL (Service Commun des Laboratoires) carried out tests on nine menstrual cups available on the French market, such as: migration tests to determine the presence of phthalates and other plasticisers, and tests to determine the content of volatile organic matter according to the conditions of the Order of 25 November 1992 on silicone elastomer materials and articles brought or intended to be brought into contact with foodstuffs, food products and drinks. Each test was repeated three times on three identical articles. The chosen test conditions were based on Regulations related to materials and objects intended to come into contact with foodstuffs, namely the French Decree of 25/11/1992, Regulation (EC) No 1935/2004, Regulation (EC) 10/2011. Thus, the migration test conditions adopted were as follows: ethanol at 10% v / v, 24 hrs, 40°C, a section immersed in 100 mL of simulant (see footnote)[35]. During migration tests, no phthalate or plasticiser were quantified. In tests to determine the VOC and total migration content, results obtained suggest an incomplete polymerisation and insufficient removal of residual volatiles after crosslinking, probably due to a missing or insufficient post-curing step in the processing of the silicones.

KEMI carried out testing of the worst-case scenario to test the presence of substances of concern in menstrual cups, and concluded that the calculated exposure was lower than the exposure level considered, and that the risk of health effects during the use of these products is controlled and very low.

Öko-Test analysed 15 menstrual cups for the presence of harmful substances. The products were subjected to a stress test to analyse the release of plasticisers and the presence of potentially harmful silicone compounds. The laboratories found hardly any substances of concern in the menstrual cups in the test. All in all, more than half of the products tested were qualified as "very good". The silicone compound D4 was only detected in one cup. This is suspected of endangering reproduction and classified as hazardous to the environment. The silicone compounds D5 and D6, which are found in a total of four menstrual cups, are also harmful to the environment. In four of the menstrual cups tested, volatile compounds can form, for example if the cups have not been sufficiently heat-treated after production (Öko-Test, 2020).

4.3 Environmental analysis, innovation and best practices

This section addresses general data about European Absorbent Hygiene Products to identify the material composition of commercialised products and technological innovations in the manufacture of AHPs in view of newer approaches for this product group.

4.3.1 Overview of material composition of disposable AHPs and reusable alternatives

4.3.1.1 Disposable AHPs

A typical layer of an external disposable absorbent hygiene product such as a baby diaper or a feminine care pad consists of a fluid permeable top sheet, an optional distribution (also known as acquisition) layer, a superabsorbent core, and a fluid impermeable back sheet with and without adhesives (**Figure 26**).

The layer structure of baby diapers, feminine care pads, and adult diapers are very similar. For all of them, the top sheet commonly consists of a thin layer of perforated polypropylene and/or polyethylene non-woven (Dey et al., 2016). The primary purpose of an efficient top sheet layer is to rapidly facilitate the inlet of liquid to the acquisition/distribution layers, also with minimal rewet, providing efficient uptake of urine to the absorbent core (Easson et al., 2018).

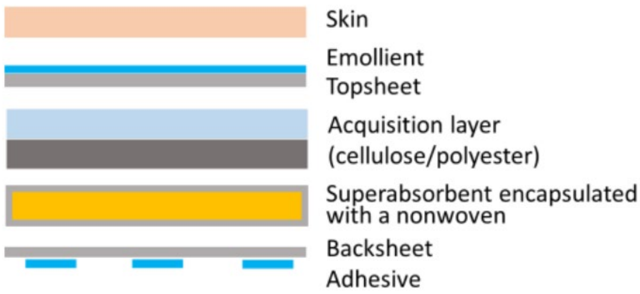
Between the top sheet and the absorbent core, there may be an optional distribution layer. This layer is composed of a cellulose cover and a polyester nonwoven. The layer helps the spread of fluid uniformly around the whole zone. In addition, this layer retains the fluid, and helps to transfer the fluid to the next

[35] Standards followed: Free MOV: ANA PRT 257, Global migration: NF EN 116-3; Specific migration: NF EN 13130-1

absorbent layer. Underneath the distribution layer, there is the absorbent core which acts as a fluid storage layer. The absorbent core layer is constituted of a blend of superabsorbent polymer granules and fluff cellulose, which are encapsulated by cellulose or polypropylene non-woven. The superabsorbent polymer (SAP) is usually made from sodium polyacrylate granules. It transforms into a gel-like substance once it gets wet and absorbs up to 30 times its liquid weight. The cellulose fluff in the absorbent core helps to absorb liquid quickly and transfer it to SAP. Then, fluid is locked and stored within this core layer (Bae et al., 2018).

The backsheet is generally made of a waterproof polyethylene or polypropylene film laminated with polypropylene non-woven that serves as a microporous barrier. This layer of small pores prevents fluid from leaking. In the case of feminine pads, there are adhesives in the backsheet that allow it to be held on cloth (Dey et al., 2016).

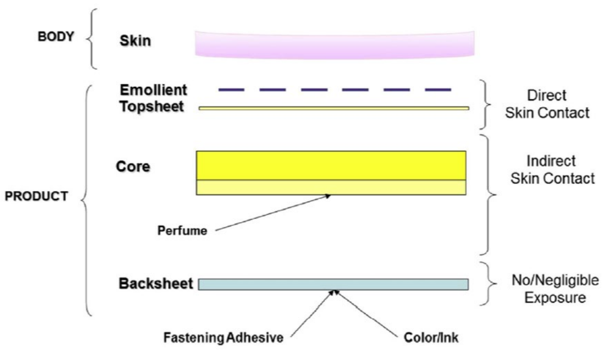
Figure 26. Layer construction of disposable care pads and diapers.



Source: Bae et al, 2018.

Most sanitary pads employ cellulose-based cores. Woeller and Hochwalt (2015) described the safety evaluation of a menstrual pad with an emollient-treated top sheet and a thin and non-cellulosic novel polymeric foam core (**Figure 27**). This sanitary pad has a conventional layered design: a fluid permeable surface (topsheet), an absorbent core, and impermeable backing with adhesive (backsheet). The top sheet is a polyethylene/polypropylene non-woven fabric bearing an emollient finish; the core comprises a two-layer, low-density, open-celled, polyacrylate polymer foam; and the back sheet consists of an impermeable pigmented polyethylene film with a panty-fastening adhesive. Scented versions of the pad contain a small amount of perfume applied between the back sheet and the undersurface of the core.

Figure 27. Pad components with respective consumer exposure.



Source: Woeller and Hochwalt, 2015.

Nowadays, over 90% of disposable tampons is based on a **cellulosic absorbent material** like rayon or cotton or a mixture of these fibres (Ajmeri and Ajmeri, 2014). In general, the absorbent core is covered by a thin layer of non-woven or perforated film that helps to reduce loss of fibres and makes the tampon easy to insert and remove. The withdrawal cord that is necessary to remove the tampon is usually made of cotton or other fibres and can be coloured (Ajmeri and Ajmeri, 2014).

Although **cotton** has been a commonly used material in AHPs as it shows breathability, absorbency and tensile properties (Sun et al., 2002), an important advantage is that it is hypoallergenic. It has been reported that synthetic fibres like rayon and polyester can produce skin problems, thus all-cotton feminine hygiene products, either disposable or reusable, are a choice for sensitive skin (Organyc, 2021). For the same reasons, cotton diapers are also available in the market (Cotton Incorporated, 2021; The fabric of our lives, 2021).

Cotton can be used in AHPs as a cotton-surfaced spun-bond composite non-woven, and cotton-centred composite, with spun-bond and melt-blown non-woven forming the outer surfaces of absorbent hygiene products (Das, 2014).

The cotton fibres used in products ecolabelled with the Blue Angel must be 100% sourced from controlled organic cultivation or from fibres from the conversion phase and must comply with the requirements of Regulation (EC) No 834/2007 (EC Organic Regulation) (Blue Angel, 2021). In the case of Nordic Swan, if the cotton is present in more than 5% of the weight of the product then it must be organically cultivated or cultivated in the transitional phase to organic production; only the string on tampons is exempted from the requirement (Nordic Swan, 2021). Similar requirements are currently set in the EU Ecolabel (European Commission, 2014).

Other common material used in AHPs is **man-made cellulose or regenerated cellulose fibres**. Regenerated cellulose fibre is a type of manufactured or man-made fibre that uses cellulose (mainly from wood or plant fibres) as a raw material. The two major regenerated cellulose fibres are viscose rayon and lyocell rayon, while others are cupro and acetate fibre. Regenerated cellulose fibre has a smooth and lustrous appearance much like silk (although it is chemically different), and the excellent water absorption ability of cotton (Chen, 2015). Tampons are made from viscose/rayon, a blend of viscose/rayon with cotton, or all cotton fibres (either organic or non-organic cotton) while in the case of sanitary pads, rayon can be part of the surface cover or the distribution layer (AHPMA, 2021).

Man-made cellulose fibre can, as well as from wood, also be obtained from non-wooden lignocellulosic materials, such as bamboo or hemp and commercialised into disposable baby diapers (OVAM, 2018; UNEP, 2021). Examples of market products made of bamboo are Andy Pandy (Andy Pandy, 2021), Bamboo Nature (Bamboo Nature, 2021) and Tooshies by Tom (Tooshies by Tom, 2021).

Criteria for man-made cellulose are already set in the current Blue Angel, Nordic Swan and EU Ecolabels. More details about proposal changes are provided in the Technical Report for the current revision of the criteria on AHPs for the EU Ecolabel.

4.3.1.2 Menstrual cups

Reusable menstrual cups can be made out of various materials, with **medical-grade silicone, rubber and thermoplastic elastomer (TPE)** the most commonly used. Silicone and thermoplastic elastomer are the most demanded types due to their hypoallergenic properties. Latex is no longer commonly used due to its stiffeners and uncomfortableness (Klinter, 2021), as well as the possible risk of allergies related to the use of natural rubber.

One of the main techniques for manufacturing menstrual cups made out of thermoplastics is **injection moulding**. In practice, the plastic is softened by heat and then injected into a mold before being cooled (Naessens and Naessens, 2017). Meanwhile, in the case of silicone menstrual cups, the silicone is cooled before being injected into a heated mold and vulcanised to produce the final part (Naessens and Naessens, 2017).

Overall, it shall be noted that the menstrual cup material needs to be resistant to multiple use and sterilisation (often in microwave). Manufacturers recommend a life-span of **3 to 5 years for TPE menstrual cups while medical-grade silicone cups can last up to 10 years** (manufacturers' data, Hait and Powers, 2019). Silicone is normally the preferred material for reusable menstrual cups due to its resistance and chemical inertness. Silicone used for manufacturing of menstrual cups is a linear polydimethyl siloxane elastomer, which permanently deforms under stress. For the deformation to be reversible, when the stress ceases, it is necessary to create bonds between the linear chains (crosslink the polysiloxane). The main chemical reactions which allow the formation of silicone rubber are by formation of free radicals induced by hot activated peroxides or by hydrosilylation, catalysed by platinum complexes. The peroxide reaction was used in the first generation of medical silicones but is no longer commonly used. It leaves an acidic residue on the surface which must be removed by a post-molding curing process. This silicone is inexpensive and can emit volatile organic compounds, especially under the effect of heat. Thus, it is most often used for single-use products and not for reusable menstrual cups (ANSES, 2018).

The silicones obtained by platinum (Pt) catalysis have a high level of purity and do not transfer residues (ANSES 2018). The Pt catalyst, hexachloroplatinic acid hexahydrate, is mixed in very small proportions with the polysiloxane. Platinum curing silicones seem to be the predominant types for menstrual cups, according to exchanges with silicone producers.

Additionally, the information exchange with chemical suppliers suggests that the enclosure of the catalysis process and a high level of control at manufacturing plants limit the release of Pt to the environment. Silicone polymers are not water-soluble and so do not promote migration of Pt catalyst to wastewater. Pt catalyst is trapped inside the polymers after curing, with minimal post-cure migration. Under the regulatory test methods that are specifically designed to maximise migration and leaching from the polymer, only very low-level ppm of Pt are typically reported, complying with - and even being lower than - the allowable levels set in the regulatory guidelines[36]. Some menstrual cup manufacturers have been found to use a heat exchange system for heating the inside of their production facilities, and closed recirculating cooling water systems.

However, some cups are being manufactured from food-grade silicone and can typically be found in the European market. Among the tests carried out by the SCL (Service Commun des Laboratoires) in 2019, it was found that the free VOCs were greater than 0.5% w/w in the case of food-grade menstrual cups, which suggests insufficient removal of residual volatiles after crosslinking, probably due to a missing or insufficient post-curing step in the processing of the silicones. Moreover, the addition of food colouring dyes or pigments should also be carefully considered as it may compromise the quality of a menstrual cup and lead to potential environmental impacts. More evidence is needed to determine whether menstrual cups manufactured using silicones in compliance with the positive lists of the Food Contact Regulation can be considered to be of the same quality as menstrual cups manufactured with silicones tested according to relevant biocompatibility criteria and showing no adverse effects in these criteria (usually known as medical silicone)[37].

Finally, there is a silicone known as antimicrobial silicone which has undergone a treatment with silver ions after being moulded. Silver ions are nanoparticles, which, depending on their size, can pass the skin barrier and whose effects on both health and the environment are unknown. ANSES has notably admitted an opinion on 5 March 2015 in which it highlights that knowledge of the potential health and environmental effects of silver nanoparticles is still insufficient (ANSES, 2015).

With regards to **packaging**, menstrual cups are normally sold inside a cardboard box together with a washable, textile (usually cotton) pouch with a closing mechanism. The protective pouch is used for storing a cleaned cup during non-flow days. Some menstrual cups may even come with a container for sterilisation as the cup must be washed in clean, boiling water as per the manufacturer's instructions.

4.3.1.3 Other reusable AHPs (textile-based)

Disposable options for baby diapers and feminine care products are usually made of cellulose and polymers in different forms and compositions. On the other hand, **reusable options found in the market are fabricated using textiles and a large variety of fibres** including cotton, wool, bamboo, hemp and man-made fibres such as modal or polyester. These materials are sometimes used in combination with each other to create the absorbent layers of cloth diapers (Bachra et al., 2020; The Natural Baby Company, 2021).

The development of modern cloth diapers is poorly covered in scientific literature. However, it must be emphasised that important changes in materials and formats have led to increased user-friendliness over recent decades. To optimise demands on absorption potential, impermeability, breathability, design, user-friendliness and durability, different fabrics are used and combined in various manners (Hoffman et al., 2020).

A modern cloth diaper typically consists of two main layers, an absorbent and an impermeable or waterproof cover. As absorbent material, the most applied material is pure cotton or cotton in blends with polyester.

[36] Centre Europeen des Silicones, Analysis for Platinum in Cured Silicone Rubber (Baby Teats) and in Extracts from the Silicone Rubber, July 2002.

[37] Difference Between Food Grade and Medical Grade Silicone. Available at: http://files.differencebetween.com/wp-content/uploads/2017/09/Difference-Between-Food-Grade-and-Medical-Grade-Silicone.pdf

Furthermore, absorbents from other natural, chemical or synthetic fibres can be found, such as bamboo fleece, hemp/cotton blends and microfibres from polyester and polyamide (Bachra et al., 2020; Hoffman et al., 2020).

There are **reusable baby diapers** made of natural materials such as hemp, bamboo and cotton already available as commercialised products (OVAM, 2018). Brand examples available in the market are Little Lamb (Little Lamb, 2021), Hippybottomus (Hippybottomus, 2021) or Pandas by Luvme (Pandas by Luvme, 2021). However, the reusable options for either baby diapers or feminine care products are textile products ouside the scope of current Ecolabels such as the Nordic Swan, Blue Angel or EU Ecolabel (Nordic Swan, 2021; Blue Angel, 2021; EU Ecolabel, 2014).

Reusable cloth pads are sanitary pads with cloth as the absorbent core. Innovation in design of reusable cloth pads has led to the use of many types of fabrics as the absorbent core and of non-cloth materials such as polyurethane material for the top sheet and bottom leak-proof layer. The variety of fabrics that are used range from pure cotton to different types of synthetic materials, with multiple variations of polyester being the most popular (Mahajan, 2019).

There are many brands commercialising innovative reusable pads made of different materials (Mulherkar, 2020). There are two main approaches, one line is the manufacturing of single-use biodegradable menstrual pads and the other is the production of reusable cloth pads. Biodegradable options include the manufacturing of pads from corn starch, bamboo or banana fibres for example (Luchese et al., 2021).

Period or menstrual underwear is manufactured with similar materials to reusable baby diapers and reusable cloth pads. Period underwear looks similar to normal underwear but with a pad inserted within the textile for fluids absorbency (Cabrera and Garcia, 2019).

Reusable menstrual products are not well represented in literature (UNEP, 2021). The only scientific study considering a locally produced reusable pad showed that the environmental impacts of the reusable pad were found to be strongly dependent on the geographical context, and in particular on how the pad is washed during its use phase (Leroy et al., 2016). The reusable pad considered was made of 100% cotton in India. Although there is a lack of studies on reusable pads and period underwear, it is reasonable to draw comparisons with the wider literature on baby diapers, as these are made of very similar absorbent materials (UNEP, 2021).

4.3.2 Innovation and best practices

This section explores the main innovations found nowadays in relation to manufacturing techniques, biodegradable materials or biobased materials currently used in AHPs.

The designs of AHPs have changed considerably over the years, particularly in terms of dematerialisation, the use of superabsorbent polymers and a greater inclusion of biobased materials. This may mean that currently available studies will become outdated if further innovation is seen in these products and policies should account for likely future developments in product designs, materials and production processes (UNEP, 2021).

4.3.2.1 Bonding techniques

Disposable diapers consist of **separated layers bonded together** as an absorbent sheet. Each layer is made of a specific raw material working complementarily to each other to guarantee the serviceability of the final products. This can also be applicable to sanitary pads and incontinence diapers for adults (Kakonke et al., 2019).

Several bonding techniques are used in non-woven production, namely chemical/adhesive bonding, thermal bonding and mechanical bonding (needle-punching, stitch-bonding). Currently, thermal bonding is widely used because it offers high production rates, lower energy utilisation, and is more environmentally friendly since there are no residues to be disposed of. In this technology, the web is heated at the softening temperature of the binding material (bi-component, thermoplastic fibres) and successively cooled down the web. The chemical bonding technique that was previously used in diaper manufacturing processes was recently abandoned because of the possible risk of skin irritations caused by adhesives. Additionally, the wet surface of the cover stocks after the drying processes caused discomfort (Kakonke et al., 2019).

A recent work studied the economic and environmental impacts of diapers using thermo-mechanical and ultrasonic bonding techniques aimed to replace gluing systems in diaper manufacturing. Comparing a standard diaper vs. a glueless diaper, it was found that the glueless single-use diapers were more eco-efficient than standard single-use diapers with lower environmental impacts and greater material efficiency. In fact, glueless single-use diapers reduced consumption of raw materials by 23%, primary energy demand by 25% and global warming potential by 10%. Lower impacts of fluff pulp and SAP were also reported for glueless diapers. In total, removing the glue reduced the impact of materials bonding by 66%, also making diapers 10.6% more cost-efficient than standard diapers (Mendoza et al., 2019; Mendoza et al., 2019).

4.3.2.2 Alternative materials

In the past few decades, the overwhelming majority of innovations in absorbent hygiene products came through **composites of non-wovens prepared by using a combination of different materials and different technologies**. A large number of possibilities of combining different materials and different technologies was tried. Some of them are still being used in commercial products (Das, 2014).

Kakonke et al. (2019) also reviewed alternatives that are sustainably sourced such as chicken feather fibres. These materials could be used to replace fluff pulp/SAP non-woven sheets in the manufacture of disposable diapers to reduce environmental pollution. Although SAPs have led to lighter, convenient, effective, and safe disposable diaper products, when coupled with the inert polymers (PE/PP), they have significant environmental impacts. Chicken feathers have potential as renewable materials generated by the poultry industry. Various methods of processing the feather waste into valuable industrial products were investigated by this research group to produce a non-woven absorbent web with a higher absorbency capacity than absorbent pads currently used in the manufacture of disposable diapers. However, these materials are still at the research and development stage and are not yet ready for a full market uptake.

Musaazi et al. (2015) assessed Ugandan-designed and locally produced single-use pads (*MakaPads*) which are largely manufactured from local papyrus fibre as the absorbent material and recycled paper. Currently 4 million MakaPads are produced per year using papyrus reeds, primarily with manual labour (mostly women) and in a factory using solar power. It was concluded that MakaPads have lower potential environmental impacts than conventional imported pads across all environmental impact categories considered. Social benefits compared to importing conventional pads were also reported. MakaPads are the most affordable biodegradable sanitary pads in sub-Saharan African with more potential for manufacturing wages to lift women out of poverty than imported pads (Musaazi et al, 2015).

Biobased polymers

Traditionally, **biobased fibres** such as rayon and cellulose acetate are already covered by the EU Ecolabel for AHPs. Other Ecolabels such as the Nordic Swan consider biobased polymers in the packaging and biobased SAP in the product itself (Nordic Swan, 2021). The Blue Angel also considers the use of renewable raw materials to produce biobased plastics for the product or packaging which must be sourced from sustainable agriculture on cultivation areas that can verify that they are managed in an ecological and socially responsible manner (Blue Angel, 2021).

Biodegradable fossil-based polymers, biodegradable biobased polymers and non-biodegradable biobased polymers make up the larger ‘bioplastics’ category. Biobased plastics can be composed completely of renewable resources (biobased) or be a mixture of non-renewable (fossil-based) and renewable resources, creating a ratio of biobased material to fossil material. Biobased plastics can be chemically identical to their fossil-fuel/petrochemical-based counterparts (‘fossil-based plastic’) and will as a result have similar physical, perceptual and sensory properties (e.g. Bio-polyethylene, Bio-PE). Bio-PE and Bio-PET are conventionally non-biodegradable polymers. Biodegradable plastics are often derived in whole or in part from renewable feedstock, but do not need to be (SAPEA 2020; Nealis, 2021).

As biodegradable plastics are able to release methane under anaerobic conditions, this makes them inappropriate for landfilling. Also, they can cause problems when entering recycling systems in high quantities. Thus, biodegradable plastics should be managed through composting or anaerobic digestion, options more suited to organic streams. They can also be used as a feedstock for other biobased products. The environmental benefits of biodegradable plastics are obtained when waste separation and processing are carried out in an effective manner, avoiding leaving them in the open environment, landfill or inadequate recycling streams (SAPEA, 2020).

On a different note, recent studies show that plastic products made from biodegradable polymers have similar toxicity to conventional plastics (SAPEA, 2020). Therefore, one of the questions that may arise in relation to the AHP criteria revision concerns for instance the existence of a criterion requirement where for each product the usual biobased carbon share of the molecule is indicated.

Biobased polymers are not currently considered in the EU Ecolabel or the Blue Angel (EU Ecolabel 2014; Blue Angel, 2021). However, the Nordic Swan sets criteria for biobased polymers based on renewable resources[38] like PLA and biobased PE. In the Nordic Swan, there is a requirement for certification of raw materials for biobased polymers when they constitute more than 20% of the total weight of the product. In fact, it sets the certification scheme to comply with, depending on whether the feedstock for the biobased polymer is sourced from palm oil, soybean oil or sugar cane (Nordic Swan, 2021).

Many biobased products are 100% biobased in terms of carbon content, but by no means all of them. In particular, products that 'combine' different molecules, such as (co-)polymers and adhesives are often only partly biobased (Spekreijse et al., 2019). Several studies have reported on the production of the bottom sheet for disposable diapers using compatibilised thermoplastic polymers comprising anything between 5% and 95% biobased carbon content i.e. starch (Spekreijse et al., 2019 and Kakonke et al., 2019). Besides, the starch industry is well developed and several sites produce PLA - polylactic acid (Spekreijse et al., 2019). However, according to some studies, these products have not reached commercial production yet. Thus, traditional thermoplastic sheets are still in use (Kakonke et al., 2019).

Another trend might be the use of plastic materials from renewable resources (e.g. PLA) as opposed to crude-oil-based plastics. At first sight, this solution could seem environmentally attractive. However, due to the existing differences between different bio-plastic production chains and to the presence of potential trade-offs between conventional and alternative plastics, a coherent and complete picture can only be taken by resorting to a LCA-based approach. As a result, a review of one LCA study, Mirabella et al. (2013), for a bioplastic-based disposable baby diaper made from 75% renewable and compostable materials was analysed. The main differences compared with conventional diapers were a reduction of SAP from 32% to 15%, an increment of fluff pulp to 55%, and substitution of polypropylene by PLA in the top sheet and of a compostable type of polyethylene in the back sheet. Also, the acquisition/distribution layer was composed of 50% PLA and 50% polypropylene. Fluff pulp was made of 100% organic and certified pulp, totally chlorine-free (TCF), and produced under the Programme for the Endorsement of Forest Certification. Sourcing and production of raw materials of bioplastic-based diapers presented the highest contribution to environmental impacts, although the materials that contribute the most vary with the normalisation method applied. A comparison of bioplastic-based and conventional diapers showed that the conventional products have higher environmental impacts in three out of the four categories, with the greatest relative weight (human toxicity, freshwater eutrophication, and marine ecotoxicity), while the bioplastic-based diaper showed the highest impact in natural land transformation. Also, energy demand was higher for this diaper than for the conventional diaper (Mirabella et al., 2013).

Currently, the major emphasis in AHP innovation is on the development of green composite non-wovens using spun-melt composites with polylactic acid (PLA) resins as biodegradable composite films with hydrophobic and/or hydrophilic properties. However, since 100% PLA non-woven webs do not meet the flexibility, tactile softness and smoothness specifications desired in hygiene products, the PLA is usually combined with polyolefin resins in a core-sheath configuration, where spun PLA fibres form the core section and PP or PE forms the sheath section (Kakonke et al., 2019). PLA is only compostable industrially; it cannot decompose in a landfill environment or in home composting (SAPEA, 2020).

Although the use of biopolymers could have strong positive effects on the production life cycle of a diaper, concerns about their polluting agricultural practices have to be considered (Mirabella et al., 2013).

All in all, it seems that **biodegradability in AHPs has no clear benefits due to the EoL scenarios of this product group**. However, the production phases of bioplastics could present lower impacts in certain environmental categories plus the advantage of not having to rely on non-renewable fossil resources.

As there are no recently available LCA studies comparing AHPs manufactured from fossil resources as opposed to AHPs made from renewable feedstock, general studies on plastic origin seem relevant.

A comparative LCA study of polylactic acid (PLA), bio-derived polyethylene, and fossil-derived polyethylene showed that the lowest GHG (greenhouse gas) emissions and FEC (fossil energy consumption) were achieved with bio-derived plastics, particularly bio-PE plastic. However, despite the benefits of biogenic carbon uptake, when landfill and composting emissions were considered for the PLA pathway, the life cycle emissions of PLA

[38] Renewable resources are defined as raw materials taken from biological materials that are continuously regenerated within a few years, such as corn and trees. (Definition by Nordic Swan, Nordic Ecolabelling for Sanitary Products, Version 6.8 • 14 June 2016 - 30 June 2024).

increase significantly, from 16% to 163% depending on the biodegradation condition, compared to the case where there is no degradation in the landfill. This study also contributed to understand the effects of the GHG emissions on biodegradability in landfill and composting scenarios which have to be taken into account when discarding the products (Benavides et al., 2020).

A recent review study of 25 articles on life cycle assessment of 50 biobased polymers and 39 fossil-based polymers was published by Walker and Rothman (2020). The authors concluded that **it was not possible to declare any polymer type as having a lower environmental impact across all analysed categories**. Significant variation was also observed among different studies of the same polymer, either fossil-based or biobased polymers. Results show that most of this variation is related to the LCA methodologies applied, in particular the treatment, the EoL treatment, the use of credits for absorbed carbon dioxide and the allocation of impacts of multifunctional processes. The raw material source and processing method assumed for biobased polymers were also a major source of variation. They also compared the studies with the European Commission Product Environmental Footprint (PEF) but concluded that none of the case studies achieved full compliance with the standard. However, it was possible to rank studies in order of the degree to which they did comply with PEF methodology. Their recommendations suggested the adoption of the PEF methodology in order to understand the implications of biobased polymers while for the EoL of products, the cradle-to-grave system boundaries are recommended, if possible. This work would allow a better understanding of the limitations and benefits of both polymer types, and would facilitate the development of polymers with lower environmental impacts (Walker and Rothman, 2020).

Bishop et al. (2021) reviewed 44 LCA studies that were published between 2011 and 2020, and which comparatively analysed the environmental footprints of some bioplastics and petrochemical plastics. This review could only provide recommendations on how to develop the methodology for such comparative analyses as the currently available approach does not allow a conclusion to be reached on the magnitude of possible environmental advantages, if any.

The Blue Angel Ecolabel considers the inclusion of biobased plastic for either the packaging or the product. In both cases, the biobased plastics must be sourced from sustainable cultivation on cultivation areas that can verify that they are managed in an ecological and socially responsible manner. The list of possible certification schemes to use is set in the main text of this Ecolabel (Blue Angel, 2021). Regarding the Nordic Swan, biobased plastic percentages are set for the product and packaging (Nordic Swan, 2021).

Superabsorbent polymers

Superabsorbent polymers (SAPs) have been used in hygiene products since the late 1960s. About 250 000 tonnes are used globally each year, most of which are used in disposable diapers for babies. Most SAPs for hygiene products are the **sodium salts of moderately cross-linked polyacrylic acid**. The cross-linking agents are typically glycol diacrylate or N,N'-methylenebisacrylamide. Residual monomer (which may be a skin irritant) levels are now below 100 ppm (Bajpai, 2018).

The development of biobased sodium polyacrylate (a type of SAP) has been studied to reduce the environmental impact of AHPs (Castrillon et al., 2019; Ye et al., 2016). Gontia and Janssen (2016) carried out a LCA for production of two types of sodium polyacrylate: biobased made from a lignocellulosic residue from side streams released to two pulp mills (TMP[39] and kraft), and the conventional fossil-based SAP. The latter presented lower environmental impacts than its biobased counterpart, mostly due to the concentration of fermentable sugars in the biobased material.

Additionally, the properties of biodegradable SAPs are still under study since they do not meet the minimum required absorbency (Kakonke et al., 2019). The properties of SAPs and non-petroleum-based SAP alternatives that are appropriate to be used in disposable diapers are compared in **Table 20**.

[39] Thermomechanical pulp.

Table 20. Properties of commercial SAPs versus non-petroleum-based SAP

Properties	Unit	Commercial SAPs	Bio SAPs
Colour		White	Off-white
Moisture content	Wt-%	3.2	13.0 max.
Free absorbency	g/g	58	-
Free absorbency in 0.9% NaCl	g/g	-	24.0 min.
Free absorbency in tap water	g/g	-	49-55
Retention capacity	g/g	34.0	Not specified
Absorbency under load (0.7 psi)	ml/g	22	6.4
Residual monomer	ppm	350	N/A
Bulk density	g/ml	0.64	0.52-0.70
pH	-	6.1	5.5.-7.5
Particle size distribution through 20 mesh (850 µm)	%	0.5	1.0 max.
Particle size distribution through 100 mesh (150 µm)	%	2.5	10.0 max.

Source: Adapted from Kakonke et al., 2019.

Sanitary pads with a lower content of SAP have recently been developed (Shibly et al., 2021). In this study, sodium alginate and cellulose-based hydrogels were used over SAP as absorbent materials. The results offered a similar performance compared to commercial products and a certain degree of biodegradability in their composition (Shibly et al., 2021).

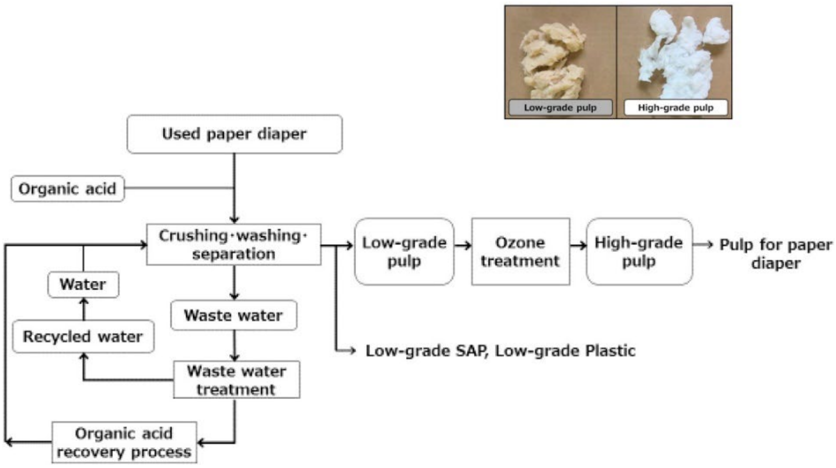
The common trend today targets manufacturing of thinner diapers with a higher SAPs content. The development of new materials has made it possible to gradually replace a certain percentage by weight of fluff pulp with SAP. The weight of diapers has been slightly reduced while the percentage of plastic materials has increased from 54% to 78% (Nealis, 2021).

In the Nordic Swan, biobased SAPs are considered one of the possibilities to account for a certain percentage of biobased materials in the AHPs (Nordic Swan, 2021). The Blue Angel sets requirements for the facilities where SAPs (biobased or synthetic) are manufactured, requesting systems to save water as well as waste and energy plans (Blue Angel, 2021).

4.3.2.3 Innovations in recycling of AHPs

Recently, the possibility of recycling adult incontinence diapers for the production of new ones was reported. Ishii et al. (2021) published a process (**Figure 28**) able to recover pulp fibres from used paper diapers after polymer separation, while simultaneously sterilising and disinfecting pulp fibres with ozone treatment and efficiently recycling used paper diapers into high-quality pulp. A standard test to evaluate the safety of the recycling process for producing recycled pulp for adult paper diapers in accordance with FDA (US Food and Drug Administration) guidelines was used on the recycled material, obtaining decontamination rates above 99% (Ishii et al., 2021).

Figure 28. Recycling process used to produce recycled pulp for the adult paper diaper



Source: Ishii et al., 2021

Discarded AHPs are managed in different ways around the world according to customs, economic restrictions, and available technology, as shown in the examples in **Table 21**. In most developing countries, where there is no segregation of waste, AHPs are collected and disposed of with urban solid waste, which usually leads to landfills or dumpsites. However, regulations regarding segregation, storage, or transportation of AHPs exist in different cities or countries. Consumers typically do not have specific obligations regarding the management of AHPs. However, some of the recommendations issued by producers or governments include discarding and flushing stools (Velasco Perez et al., 2020).

The use of specific bins for AHP waste in commercial and government facilities is a common practice in developed countries. In the UK, according to the Environmental Protection Act Section 34, focused on the duty of care (Parliament UK, 1990), employers must provide means for disposing of sanitary pads, tampons, and liners, which is commonly done using sanitary bins. Commercial premises with baby changing facilities also need to provide specific disposal bins. Management options for AHPs differ greatly depending on urbanisation, availability of waste treatments, health considerations, local customs, and cultural issues as **Table 21** illustrates for several countries and cities (Velasco Perez et al., 2020).

Table 21. Classification of AHPs and waste management in different cities or countries

City/ Country	Classfication of AHPs	Treatment
Hamburg, Germany	Non-recyclable	Waste to energy
Helsinki, Finland	Mixed waste	Waste to energy
Nakao, Japan	Combustible	Waste to energy
Toronto, Canada	Organic	Anaerobic digestion
Mexico City, Mexico	Inorganic of limited valorisation	Landfill
Spain	Residual fraction	Mechanical-biological treatment, incineration of landfill
Costa Rica	Ordinary waste	Landfill
India	Dry waste	Landfill, incineration
Zimbabwe	Mixed household waste	Illegal dumpsites
Thailand	Mixed household waste	Landfill or illegal dumpsites
Pakistan	Mixed household waste	Landfill or illegal dumpsites

Source: Adapted from Velasco Perez et al., 2020.

The latest publications deal with innovative EoL scenarios for AHPs; however, few of them show examples of the conversion of used AHPs into other valuable products (Karimi et al., 2020). A recent application of waste diapers is the use of the shredded diapers to modify the viscosity of cement grouts and concrete. In this manner, the rheological properties of cement pastes and self-consolidating concrete can be modified for higher yield stress value, plastic viscosity and apparent viscosity of cement composites, thus improving their desired properties (Karimi et al., 2020).

Another example is the degradation of used baby diapers with the edible fungus *Pleurotus ostreatus*, which reportedly decreased the volume of AHPs and rendered a valuable product that could be used as forage (food product with high protein content and free from pathogenic organisms). They used a mixture comprised of different types, sizes and trademarks of disposable used baby diapers. The technique tested led to a reduction of more than 85% of the mass and volume of waste, indicating that growing *P. ostreatus* on disposable diapers could be a good alternative for two current problems: reduction of urban solid waste and availability of high protein food sources (Espinosa-Valdemar et al., 2011). This same group of researchers published a small study on composting of used baby diapers with garden waste, finding that 87% of the mass of diapers was biodegraded and reduced (Espinosa-Valdemar et al., 2014).

Takaya et al. (2019) studied the recyclability of collected AHP waste from health-care institutions in England and their findings suggested that nearly 50% of the total superabsorbent polymer could be recoverable from fluff pulp fractions, thus being unaffected by the presence of ionic species typically present in human waste. On the other hand, recovery of mixed plastic packaging was more challenging. Overall, this research concluded that AHP recycling is possible if recycled materials are targeted towards non-food-related market outlets such as the construction and land remediation sectors (Takaya et al., 2019).

The production of biohydrogen by dark fermentation (Sotelo-Navarro et al., 2017) has also been studied. The significant content of cellulose in disposable diapers indicates that this waste could be an attractive substrate for biofuel production. However, the process achieved a low hydrogen yield, attributed to mass transfer limitations and possible interference by the presence of SAP (Sotelo-Navarro et al., 2020).

A Japanese patent reported the production of combustible pellets from used baby diapers to be used in a biomass boiler. In this system, the used diapers go through several steps: shredding, fermentation and drying. The outcome are fluffy bacteria-free fuel chips to be supplied to in-house and/or neighbouring facilities (Super Faiths Inc., n.d.).

Khoo et al. (2019), enumerated industry examples such as Knowaste (UK) or Fater (Italy). Knowaste has a recycling capability of 360 000 t/year−1 of sanitary products while Fater can process up to 100 000 t/year−1, recovering 150 kg of cellulose, 75 kg of mixed plastics, and 75 kg of SAP per metric tonne of processed AHP waste (Khoo et al., 2019). There is a demonstration European project from the BBI JU[40] which is currently studying the possibility of recycling the cellulosic fraction of post-consumer AHP waste for producing biobased building blocks, polymers and fertilisers (EMBRACED project, 2021).

However, the main challenge for recycling AHPs is the economic viability of the process. A competitive recycling project must fulfil several conditions such as high population density and people's participation; emerging product stewardship mandates; government recycling incentives; landfill material bans or high gate fees; high costs of incineration; transport distance from collection areas to the treatment plant; and a constant provision of feedstock (Velasco Perez et al., 2020).

4.3.2.4 Innovations in recycling of menstrual cups

Regarding the EoL of silicone-made reusable menstrual cups, one manufacturer of TPE and silicone menstrual cups (Me Luna GmbH) indicates that: '*silicone rubber cannot be recycled by simple processes. The recycling of a single used cup is difficult to be done as the requirements for material purity and safety cannot longer be guaranteed*'. According to Breuillac 2019: '*the recycling of rubbers is not possible as they are a kind of thermoset and the presence of static covalent bonds between polymer chains prevents them from flowing and being reprocessed'*. Nonetheless, the manufacturer Me Luna GmbH claims that the thermoplastic elastomer can be recycled without problems. In their production line, defective parts can be returned to the running production process.

[40] Bio-based Industries Joint Undertaking (BBI JU) https://www.bbi.europa.eu/

4.4 Life Cycle Assessment of AHPs

Life cycle assessment (LCA) is a tool conventionally used to calculate the environmental impacts of a product or a system. The methodology is defined in the standard ISO EN 14044. The Product Environmental Footprint (PEF) is a multi-criteria measure of the environmental performance of a good or service throughout its life cycle (Manfredi et al., 2021).

The first products to be analysed in LCA studies within the AHP group, and in general the most often, are children's diapers. After the introduction of single-use diapers, consumers started to wonder about the most environmentally friendly choice between the available diaper systems (single-use vs. reusable). Three LCA studies comparing single-use and reusable cloth diapers have been analysed. Besides, four LCA studies comparing single-use diapers with improvement in design were also examined. In all cases, the introduction of sustainably sourced material showed a better environmental performance. However, disposal scenarios are crucial in order to obtain a real benefit from innovative production. To fulfil this purpose, four studies comparing single-use diapers with a focus on EoL scenarios were analysed. The best method for recycling and disposal of diapers (or any absorbent hygiene products) is not yet known. Consideration of any method to be applied might differ by country, and industrial prospects in terms of overall cost, profit margin, social and environmentally friendliness.

On the other hand, feminine care products are only occasionally the subject of LCA studies. Only one peer-review study that conducted a full LCA of three menstrual products: disposable tampons and sanitary pads, and reusable menstrual cups was found. Two other LCA studies based on a limited range of products were analysed, while another study presented at a conference is mentioned. LCA studies on breast pads are not available at the moment.

4.4.1 Overview of published LCA studies

LCA studies on baby diapers have been published as far back as from the late 1980s and the 1990s. These studies either compared single-use and reusable options or just assessed the environmental impacts of one specific product group (Lentz et al., 1989; Fava et al., 1990; Vizcarra et al., 1994; Hakala et al., 1997). The mentioned studies concluded that single-use and reusable systems come with different environmental impacts. While the use of water is significantly higher in reusable diaper use, more waste is produced and more raw materials are needed for the production of the single-use diaper.

More studies have been produced since 2000, when awareness on environmental issues, plastic production and disposal in relation to consumption of goods and resource depletion has been rising. Looking at the comparative LCAs on single-use and reusable baby diapers, **Aumônier et al. (2008)** concluded that the manufacture of disposable diapers had a greater environmental impact than their waste management by landfill. The study showed that the impacts for reusable diapers were highly dependent on the way they were laundered. This study was performed using UK conditions and built on their 2005 study, updating the diaper systems with more recent electricity, energy consumption, manufacturing and waste management data. The study compared a standard disposable diaper, the *Terry towel* diaper, a pre-folded cloth diaper and a cloth-shaped diaper. As impact assessment methodology, CML 2001[41], was used. The impact categories analysed were global warming, ozone depletion, photo-oxidant formation, depletion of abiotic resources, eutrophication, acidification, human toxicity, aquatic and terrestrial toxicity measures. Unlike those of single-use diapers, it showed that the environmental impacts of reusable options are driven by consumer behaviour. Sensitivity analyses found the most important variables to be whether putrescible waste was removed from the reusable diapers before washing, the percentage tumble dried and the age of the washing machine. Global Warming Potential (GWP) was about 4% higher than in the single-use system. Washing diapers at fuller loads while at the same time eliminating dryer use, switching to line-drying and reusing the diaper system for a second child decreased the environmental impacts to 45% of the impacts associated with the single-use system. If consumer behaviour changes in a way that washing temperatures are increased to 90°C and laundry was always tumble dried, the GWP is around 80% higher compared to single-use systems. Therefore, no clear environmental preferences could be observed for any of the product systems.

[41] Developed by Centrum voor Milieuwetenschappen Leiden (CML), the Institute of Environmental Sciences at Leiden University

O'Brien et al. (2009) performed a LCA on reusable and single-use (disposable) diapers in Australia. Two reusable scenarios were considered, that of diapers washed at home and that of diapers washed in a commercial laundry. The diaper systems were evaluated against four inventory-level categories, namely water resource depletion, non-renewable energy depletion, solid waste (mass) and land area for resource production. For single-use diapers, over 90% of water and energy consumption and land use could be attributed to the production stage. Home-washed reusable diapers, washed in cold water in a front-loading washing machine and line-dried, used less energy and land resources and comparable water resources, and produced lower quantities of solid waste, than single-use diapers. Single-use and commercially washed reusable diapers had similar ranges in energy resource depletion. Pulp production accounted for 75% of non-renewable energy resource depletion in single-use diapers, even with 46% of energy used for pulping being from renewable sources. Most of the energy resource depletion in commercially laundered diapers (56% to 62%) was due to transporting the diapers between the home and the laundry. Single-use diapers required substantially more land area for resource production than reusable diapers did, and commercially washed diapers required two to three times more land area than home-washed diapers. This was because commercially washed diapers had a shorter lifespan and more cotton was required.

Hoffman et al. (2020) compared single-use and reusable baby cloth diapers in a recent study. They assessed the environmental impacts of four different product systems, namely a standard disposable diaper, a cloth diaper with a diaper-as-product business model using domestic laundry, a cloth diaper with a simple diaper-as-service model using on-premises laundry and a cloth diaper with an optimised diaper-as-service model using industrial laundry. The functional unit was one toilet-trained child and the geographic scope was Brazil. They found that reusable diapers had lower potential ecosystem and human health impacts and lower potential damage to ecosystems than single-use diapers. The poor performance of disposable diapers was mainly due to their EoL treatment, which consisted of sanitary or unsanitary landfill, provoking high greenhouse gas emissions. For cloth diapers, conventional diaper-as-product and alternative diaper-as-service models were assessed, which differed in laundry methods and efficiency. The most advantageous product system according to this study would consist of a diaper-as-service model, using large-scale continuous batch washers. The economic feasibility and willingness of consumers to engage with this business model has yet to be proven. Diaper-as-service models in on-premises laundry showed poorer environmental performance, due to higher water and energy needs.

Cordella et al. (2015) studied the evolution of disposable baby diapers in Europe with a LCA and identified key areas of improvement. The outcomes of the study served to support the design and the labelling of products. The functional unit was the production and consumption of one unit of product. The assessment covered the product's life cycle from "cradle to grave", which was subdivided into four subsystems: (1) production and supply of materials and packaging; (2) manufacturing of the product; (3) distribution; and (4) product disposal (EoL). Impacts were quantified according to the CML 2001 method and the LCA was carried out to quantify the environmental impacts associated with average products available on the European market in 2011 and in previous years (i.e. 1987, 1995 and 2005). The impact categories studied were abiotic depletion potential for mineral resources, acidification potential, eutrophication potential, global warming potential, and photochemical oxidation potential. The results showed an apparent correlation of the environmental impacts of disposable baby diapers with the amount of materials used in the product. Fluff pulp was the most used material in 2011 and that generated the highest contribution to the environmental impacts. Superabsorbent polymer (SAP) was the second most significant contributor in most of the impact categories while impacts of packaging appeared negligible. Under the assumptions made in the assessment, smaller contributions were registered for other life cycle stages although the EoL may be relatively more important for some impact categories (e.g. eutrophication, global warming, photochemical oxidation). The historical analysis of average products between 1987 and 2011 showed that the introduction of SAP and progressive decrease in use of materials led to lighter products over time. With respect to the EoL stage, incineration seemed the best available option for this product group while alternative forms of treatment oriented to material recovery and recycling could require significant structural changes to the waste management system. The study's data inventory was based on literature searches; however, consensus from industry was acknowledged, which makes this study a good example in 2021.

Other improvements in design have focused on the introduction of biobased material as shown by the LCA on disposable diapers performed by **Mirabella et al. (2013)**. This study evaluated the life cycle impacts of a biobased diaper and compared the eco-design and eco-innovation of the "WIP" diaper produced in Italy with a standard diaper produced in the UK (with data from Aumônier et al., 2008). The study substituted two different bioplastics (PLA and a starch-based biopolymer) for a significant proportion of the petroleum-based plastics in a standard disposable diaper. It was focused on material production and product manufacturing (cradle-to-gate) and investigated three EoL scenarios in a sensitivity analysis: (1) bioplastic diaper, composting; (2) bioplastic diaper, landfill, composting and incineration; and (3) standard diaper, landfill and incineration for a functional unit of one diaper. It used the ReCiPe 2008 method and 18 impact categories were analysed, including climate change, human toxicity or particulate matter formation among others. It was concluded that the biobased single-use diaper had a better environmental profile than a standard single-use diaper with lower potential environmental impacts across a number of impact categories (including climate change), but had higher agricultural land occupation, land transformation and water depletion. The study identified several areas to improve the environmental profile of the biobased diaper, including selecting biopolymer suppliers on the basis of their environmental performance, reducing transport distances along the supply chain, and ensuring the diaper was composted at EoL. Use of biopolymers could have strong positive effects on the production life cycle of a diaper, but the study also highlighted several concerns about their polluting production phases, i.e., agricultural practices and energy generation.

Mendoza et al. (2019) carried out two studies to evaluate the economic and environmental impact of using an optimised absorbent core and innovative bonding technologies to replace gluing systems in diaper manufacturing. They studied a standard diaper vs. a glueless diaper in Europe with a functional unit of manufacture and use of 1 000 baby diapers. They applied the CML 2001 method with 12 impact categories. It was concluded that glueless single-use diapers are more eco-efficient than standard single-use diapers, with lower environmental impacts on a range of indicators including consumption of raw materials, primary energy demand and global warming potential. They also had more than 50% lower impacts in terms of eutrophication, ozone depletion, human toxicity and ecotoxicity potentials. Lower raw material inputs also reduced transport and waste management requirements. The key driver for the lower environmental impacts of single-use glueless diapers was their greater material efficiency. A sensitivity analysis that considered the effect of reducing raw materials by 15% showed that the impacts in terms of GWP and primary energy demand would be reduced by 12% and 15% respectively. When compared with standard single-use diapers, glueless single-use diapers reduced consumption of raw materials by 23%, primary energy demand by 25% and global warming potential by 10%. Fluff pulp and SAP were responsible for 44% to 85% of the impacts from raw materials for standard diapers because they account for 70% of the weight of the diaper. The impacts of fluff pulp and SAP were 1.2 and 3.7 times lower for glueless diapers as lower quantities of these materials are used. Removing the glue reduced the impact of materials bonding by 66%. However, the use of the air-through bonded (ATB) layer to build the absorbent core resulted in higher impacts from non-wovens in glueless diapers. The life cycle costs of standard and glueless single-use diapers were estimated at EUR 106.3 and EUR 95.1 respectively. As a result of greater material efficiency, glueless diapers were 10.6% more cost-efficient than standard diapers, saving 9.2 kg of material per 1 000 diapers.

Kakonke et al. (2019) explored sustainable production and consumption strategies for the production of biobased products to reduce the use of non-renewable raw materials in baby diapers. They reviewed procedures for the manufacture of disposable diapers, problems emanating from the usage of fossil-based products and use of sustainably resourced materials that could replace the fossil-based ones. They reviewed the disposable diaper market, showing that the introduction of SAPs has led to lighter, convenient, effective, and safe disposable diaper products. Despite their higher absorbency, SAPs, coupled with the inert polymers (PE/PP), have significant environmental impacts. This review reveals that there are alternative sustainably sourced raw materials such as chicken feather fibres, bamboo and hemp fibres. However, these materials are still under research and development stages.

Other recent studies focus on the LCA of the EoL scenarios for diapers and other related AHPs. **Arena et al. (2016)** investigated the technical feasibility, environmental compatibility and social aspects of a novel recycling process for absorbent hygiene products. The recycling process consisted of an autoclave coupled with a sorting machine that sterilised the waste and separated its cellulosic and plastic fractions. The plastics were recovered, while the cellulose was utilised in a bubbling fluidised bed gasifier to produce the steam used in the autoclave. The study assesses three EoL options for a standard single-use diaper where it could be recycled, co-incinerated or sent to landfill. The functional unit was the treatment of 500 kg of absorbent hygiene product waste in Italy, using the Impact 2002+ method and studying global warming, non-renewable energy, carcinogens, non-carcinogens and respiratory inorganics categories. It was concluded that recycling a single-use diaper may result in lower environmental impacts than incinerating or landfilling it, leading to significantly lower global warming potential and non-renewable resource consumption.

An innovative process was studied by **Itsubo et al. (2020)**, which developed a new technology for the closed-loop recycling of used baby diapers. The use of the recycled pulp and SAP as materials for diapers was evaluated via the environmental impact using the LCA methodology, using data obtained from experimental facilities for recycling. The functional unit was assumed as one diaper and its disposal. They studied GHG emissions, water consumption, and land use occupation. The results of the comparison of the new method with the landfill and incineration processes demonstrated a greenhouse gas reduction of 47% and 39%, respectively. The results also showed that such recycling is expected to reduce land-use occupation and water consumption, closely related to the pulp, the main raw material of baby diapers.

Other recent publications focused on the revision of the feasibility of recycling options for disposable baby diapers. **Khoo et al. (2019)** listed options as the incineration or pyrolysis; the recycling processes from Knowaste company (UK), Fater company (Italy) or Super Faiths Inc. (Japan); or the biodegradation of diaper components. Polymers can be biodegraded by microorganisms, while cellulosic materials in diapers coupled with mushroom cultivation could also be biodegraded or used for soil fertiliser and garden compost. However, there has not been a consensus on the best method for recycling of diapers or AHPs. **Karimi et al. (2020)** explored the applicability of shredded waste diapers (SWDs) as an innovative viscosity-modifying mixture for cement grouts and concrete. A model was proposed which formulated the chemicals that SWDs add to concrete. The results indicated that SWDs modified the rheological properties of cement pastes and self-consolidating concrete, increasing yield stress value, plastic viscosity and apparent viscosity of cement composites. The main challenge in recycling and valorization of waste baby diapers is the cost of the process.

LCA studies focusing on feminine care products are less abundant in the literature. While many recent studies focus on market consumption and preferences, the LCA studies are still few in comparison to baby diapers.

Cha and Park (2019) studied the consumer preference and market segmentation strategy of feminine disposable sanitary pads in South Korea. They found women's preferences for products were influenced by product function, selling price and sales-promoting means. And it was also influenced by the characteristics of purchasing distribution channels. **Peberdy et al. (2019)** explored the level of awareness people have about the environmental impact of menstrual products in the UK. Currently the most popular types of product are also the most detrimental to the natural environment, particularly due to the amount of hidden plastic in disposable items.

To date, only one peer-reviewed research article comparing the environmental impact of disposable vs. reusable feminine care products is available. Furthermore, three non-peer-reviewed studies covering a limited range of products were published in 2006 and 2015. In the previous PR, Cordella et al. (2013) performed a LCA of disposal options using literature data.

Mazgaj et al. (2006) conducted a comparative LCA between feminine care pads and tampons using SimaPro 7 software, Eco-indicator'99 as the impact assessment method while impact categories related to human health, ecosystem quality and resources were assessed. Quantitative data related to the tampon production and transportation were not considered in this LCA. Only raw materials consumption, waste generation during production and waste treatment after use were considered in the case of tampons. The following environmental impacts proved more relevant: climate change, ozone layer depletion, ecotoxicity, acidification, eutrophication, land use and use of fossil fuels and minerals. The main findings were that the most relevant environmental impacts in the pads were caused by the production of the LDPE foil. Tampons turned out to be more environmentally favourable within most of the impact categories. This was due to the different product weights and compositions: tampons are lighter and present a higher content of renewable raw materials (e.g. cotton), while petrochemical-based materials (e.g. polyethylene) are used within pads. However, the comparison is not consistent due to the missed consideration of the production and transportation process for tampons.

Cordella et al. (2013) performed a LCA for the previous EU Ecolabel AHP Preliminary Report for sanitary pads, tampons and breast pads. Results showed a clear correlation between the environmental performance and the weight of the products: the higher the mass, the higher the environmental impacts that could be attributed to the product. Fluff pulp was the key material for sanitary pads, being the main contributor in all impact categories with the exception of ADP (Abiotic Depletion Potential). For this impact category, the siliconised release paper had a slightly higher impact than cellulose, caused by the use of silicone. For GWP (Global Warming Potential), besides fluff pulp, adhesives and plastic materials such as PP, PET and LDPE also contributed comparable shares (8-13%) to the results. Looking at the LCA results for the tampon, it was apparent that the environmental impacts were almost completely due to cotton, i.e. the main component considered, and to the plastic applicator. Cotton provided the highest contribution to all the impact categories considered in the assessment apart from primary energy demand from non-renewable resources. The applicator had a strong influence on GWP, POCP (Photochemical Ozone Creation Potential) and primary energy demand from non-renewable resources due to its energy-intensive production and its crude oil origin. The PP top layer and string had a negligible influence on the results because of their low masses. For breast pads, results looked similar to those of sanitary pads: fluff pulp was the main contributor to all impact categories. SAP showed significant shares in GWP and primary energy demand from non-renewable raw materials due to its energy-intensive production. The siliconised paper was (as for sanitary pads) driving ADP due to the production of the silicon resin.

Weir (2015) assessed five menstrual products: a non-applicator tampon, a tampon using an applicator, a disposable menstrual cup, a silicone medical-grade menstrual cup and natural sea sponges. The study aimed to understand the cost and environmental performance of these five products in Canada. The functional unit was 1, 5 and 10 years of product use. They chose 10 years as the upper end because that was the experienced lifespan of the silicone medical-grade menstrual cup. Environmental indicators were calculated based on the raw materials used for each product and available from manufacturers. The raw materials information for the sea sponges was not available, therefore their results were absent. The data gathered for environmental impacts were based solely on raw materials, neglecting other sources of outputs such as land use, transportation, at plant assembly, use and method of disposal. The Ecoinvent 2.2 database using the CML - IA baseline method was applied. Five environmental indicators were chosen: abiotic depletion, fossil fuel depletion, global warming potential, acidification and eutrophication. On a single unit basis, the silicone medical-grade menstrual cup had the most environmental impact in every category; however, once products were compared temporally for one cycle and for one year, the silicone medical-grade menstrual cup had the lowest environmental impact, since one unit can be reused for a longer period of time. For the non-reusable menstrual products, on a temporal scale of one cycle and one year, the tampons with a plastic applicator had the most abiotic and fossil fuel depletion, followed by the disposable menstrual cup and then the tampon without applicator. The common factor between applicator tampon and disposable menstrual cup is the plastic components. This means that abiotic depletion and fossil fuel depletion were likely related to the amount of plastic used in a menstrual product. Similarly, the tampon with an applicator had the highest global warming potential, followed by the disposable menstrual cup and then the tampon without applicator, which likely meant that global warming potential was linked to the use of plastic in menstrual products. Tampons with an applicator had nearly double the acidification and eutrophication potential than that of the disposable menstrual cup and the tampon without applicator. This shows that acidification and eutrophication are affected almost identically for cotton/rayon products as they are for plastics. It also explains why the disposable menstrual cup and the tampon without applicator had comparable values since they are comprised of cotton/rayon and plastic respectively.

Leroy et al. (2016) analysed four menstrual products (tampon, single-use pad, reusable pad and menstrual cup) in different geographical contexts: Europe, the US and India. In this particular case, these products were studied from the environmental, economic, hygiene, comfort and social point of view. With a functional unit of 50 women for a period of 1 year and several assumptions such as the number of tampons used (156), single-use pads (208), reusable pads (6) and menstrual cup (0.1 of a cup as its considered lifespan was 10 years), they found that the menstrual cup had the best environmental performance.

Cabrera and Garcia (2019) developed a study aimed to analyse the impacts of single-use menstrual products, baby diapers and wet wipes as well as measures to prevent or minimise them. This report was the first of its kind at European level, and showed that the impacts generated during the production process of these products resulted mainly from the use of large volumes of wood pulp, cotton, or viscose rayon for the production of SAP, and other components such as polyester, polyethylene, polypropylene, adhesives, fragrances and dyes. In addition, significant amounts of water and energy might be used during the production process. Furthermore, because of the composition of these products (made of mixed material types), as well as the presence of organic material after use, recycling them is technically difficult and economically expensive. Therefore, in Europe these products typically end up in landfills (87%) or are incinerated (13%).

Hait and Powers (2019) compared three menstrual products: disposable tampons, disposable sanitary pads, and reusable menstrual cups. The study was performed applying Gabi LCA software with the Ecoinvent database and ILCD methodology for mid-point analysis. The functional unit was one year of coverage for one woman. The comparison of normalised results between the three products investigates indicate that sanitary pads have the overall worst total score, with tampons showing a 40% less of total impact and menstrual cups even 99.6% less of total impact. The use of wood pulp as a component of the absorbent material in sanitary pads had substantial benefit for reducing greenhouse gas emissions. For tampons, removing the applicator from the product substantially reduced several of the impacts and generally made them a better choice than a sanitary pad. For menstrual cups, the quantity of water required for the entire ten-year lifecycle of a menstrual cup (750 L), dominates the impact on all non-biological resource impact categories (Hait and

Powers 2019). Silicone, the sole material to make the cup and components of the raw materials manufacturing stage contribute to 20% of the energy resources, 8.8% of the CO_2 emissions and 6.3% of the non-renewable materials used for the entire life cycle. The study also highlights that the impacts of the menstrual cup are insignificant compared to the disposable products because only one tenth of one menstrual cup is required per person per year (Hait and Powers, 2019).

The recently released report from the United Nations Environment Programme (UNEP, 2021) shows the results of a not yet officially published work from **Vilabrille Paz et al. (2020)**. This study reports the comparative life cycle assessment using the Environmental Footprint 2.0 method of medical-grade silicon menstrual cups, tampons (100% cotton and conventional) and single-use pads. Their functional unit is the use of menstrual products for one year by one menstruating person, identifying the use phases such as hand washing, use of additional toilet paper or cup sterilisation. Results concluded that the menstrual cup is the most environmentally friendly product. The use phase of the menstrual cup accounts for nearly 95% of all impact categories where electricity required to boil the water to sterilise the cup, soap production and waste water treatment are the main contributors. When comparing the pads and tampons, depending on the impact category, one or another showed better environmental performance. This is also the case between the 100% organic cotton (core and string) and the conventional tampon (viscose core, non-woven core cover (PE and PP), polyester string). The production of components is the main contributor stage in both types of tampons and the single-use pad. For all products studied, the less significant stages regarding environmental impact are distribution, consumer acquisition and EoL disposal (incineration considered in all cases).

4.4.2 Summary of published LCA studies

The benefits of single-use products regarding handling use are clearly greater than those of reusable products, but at the same time they consume more material resources and produce more waste. A very limited number of these papers analyse the whole life cycle of the AHPs under the EU Ecolabel scope. As a result, the analysed literature is only sufficient to identify, qualitatively, environmental hotspots of disposable pads, tampons and baby diapers but not for breast pads.

Most of the analysed literature refers to the environmental impacts of each type of disposable absorbent hygiene product (usually pads, tampons or baby diapers) while other scientific papers encompass a comparison between disposable options and their reusable alternative.

For the disposable AHP, there are opportunities for the EU Ecolabel to set up criteria to increase the amount of materials that are biodegradable beyond the organic cotton.

Efforts should also be directed towards a higher consumer awareness on the correct product use and disposal. Despite the organic content the product may have, if the disposal is not correct, the biodegradability potential will be reduced considerably, resulting in it having the same EoL impacts as its non-organic counterpart.

Disposable vs. reusable diapers

- The LCA studies reviewed showed that the main contribution to the environmental impacts of single-use diapers is given by the production and consumption of raw materials. Transportation, packaging and EoL seem to play a less significant role in defining the environmental performance of the product.
- AHPs also make an important environmental contribution due to the electricity consumption and the chemicals used during the process. In particular, in the case of disposable baby diapers, a difference in the assumptions on the age of toilet-training, temperature of washing and energy efficiency of the washing machine results in different outcomes in different studies.
- The environmental impacts of reusable diapers are driven by consumer behaviour to a much larger degree than those of single-use diapers. Reusable diapers when washed so as to minimise water use (e.g. in a fully loaded, modern washing machine) and in an energy-efficient manner have lower environmental impacts than single-use diapers. The electricity generation mix, and consequently the geographical context, is thus an important consideration. Waste infrastructure available for the disposal of single-use diapers also varies with the geographical context, with potential solutions better suited to some contexts than others.
- However, not all LCA studies find reusable diapers to have lower environmental impacts than single-use diapers, and there is significant variability and overlap between and within diaper systems. The

main cause of these differences are assumptions made around the laundering of reusable diapers. Thus, single-use diapers generate more solid waste over their life cycles than reusable diapers, but reusable ones create impacts in their use phase.

- A reusable diaper system which optimises energy and water use has lower environmental impacts than single-use options.

Innovation in design of diapers

- Biobased, glueless and different weight diapers were found in literature with a promising reduction in the environmental footprint in the manufacture process. Design has the potential to minimise or avoid environmental impacts, notably through material reductions. The environmental benefits of substituting materials used in producing single-use diapers are not clear yet.

End-of-life scenarios of diapers

- Innovative technologies such as biodegradation, pyrolysis, and composting seem to offer high potential in terms of diaper recycling. Nevertheless, these methods are still in their infancy and possess several limitations. In any case, it seems that recycling a single-use diaper results in lower environmental impacts than incinerating or landfilling it. So far, there has not been a consensus on the best method for recycling of diapers or absorbent hygiene products. In fact, consideration of any method to be applied might differ by country, and industrial prospects in term of overall cost, profit margin, social and environmental friendliness.

Disposable feminine care products

- The main findings showed that the most relevant environmental impacts in the sanitary pads are caused by the manufacturing production of the LDPE foil.
- Tampons proved more environmentally favourable due to the different product weights and compositions (higher content of renewable raw materials such as cotton).
- For tampons, removing the applicator from the product substantially reduced several of the impacts and generally made them a better choice than a sanitary pad.

Reusable feminine care products

- Among the environmental advantages of reusable products (compared to single-use ones), waste prevention is one of the biggest factors. It has been estimated that the use of a menstrual cup results in a reduction of 99% of the waste that would be generated using single-use products.
- On a single unit basis, the silicone medical-grade menstrual cups may have the most environmental impacts; however, once products are compared temporally for one cycle and for one year, silicone medical-grade menstrual cups have the lowest environmental impact.
- Disposable tampons and sanitary pads had far greater impacts across each category than the reuseable menstrual cup. The use of wood pulp as a component of the absorbent material in sanitary pads has substantial benefit for reducing greenhouse gas emissions. However, that benefit is coupled with increased toxicity, mostly due to the potential for dioxin generation during bleaching.

4.4.3 Screening LCA study: AHPs in Europe

4.4.3.1 Summary of the screening LCA study for AHPs

The goal of the screening LCA study is to assess the environmental impacts of average disposable open baby diapers and sanitary towels using the Product Environmental Footprint (PEF) methodology. The results are not intended to define thresholds, but to find hotspots that the criteria should focus on. It should be noted that only data on open baby diapers were received, and thus used in the assessment, although EU Ecolabel criteria include all types of diapers, i.e. also pant diapers. There are no Product Environmental Footprint Category Rules (PEFCRs) for absorbent hygiene products, thus this study is performed as a screening study following general PEF methodology rules defined in Zampori & Pant (2019). The study is not intended to define PEF category rules for AHPs.

The environmental hotspots identified in this study concern mainly the production of raw materials. More specifically, the raw materials showing the highest contributions in the case of baby diapers are SAP, fluff pulp, and PP, LDPE and PET granulates, depending on the impact category. In addition to raw materials, waste landfilling was identified among the most relevant processes in the Climate Change impact category. For sanitary towels, the most contributing raw materials are viscose, fluff pulp, and PET, PP and LDPE granulates. In addition to LDPE used in sanitary towel production, the LDPE granulates used for sanitary towel packaging were also identified as a hotspot in some impact categories.

In addition to production of raw materials, transportation of raw materials and packaging to manufacturing site are also identified as having a high contribution in some impact categories (Acidification and Eutrophication - terrestrial), mainly due to the train transportation, the distance of which is based on default scenarios in the EF method (Zampori & Pant, 2019) due to a lack of supply-chain-specific data.

The Data Quality Level is good (score 2.04) for baby diapers and very good (score 1.66) for sanitary towels. Although the score for both baby diapers and sanitary towels is good, it can be seen that while the geographical and technological representativeness of the dataset is high (<3), the precision and time representativeness have lower scores. Only manufacturing of baby diapers and sanitary towels is based on primary data; all other data are secondary data from databases or literature. This is due to the nature of the study which uses data from the manufacturing companies although most of the relevant processes are beyond the control of these companies. To increase the quality of the study, more primary data should be used, especially for the processes identified as most relevant. In addition, it is not known how well the data received from companies represent the average baby diaper and sanitary towel production, because the market shares or sizes of these companies are not known. Also, it is not known whether other companies, which did not provide data, use different raw materials with higher or lower impacts.

This study was subject to third-party verification between February and April 2022. Two iterations were carried out by the third-party verifiers (who had access to the Bill of Material – BoM – of the model), and therefore an updated version of the study was developed. The conclusion from the third-party verifier of the updated study is presented here: 'The study is technically performed correctly. Due to the nature of the study not all PEF reporting requirements are fully met, but that makes no difference to the results. The updated version pays sufficient attention to the limitations and representativeness of the conclusions. The goal of the study is 'to find hotspots for which the criteria should focus on'. The hotspots are mentioned in a way that they can be used for the goal'.

4.4.3.2 Goal of the study

The goal of the study is to assess the environmental impacts of average disposable open baby diapers and sanitary towels using the PEF methodology to find out the most relevant impact categories, life-cycle stages, processes and flows of absorbent hygiene products. The results of the assessment will be used in the update of the EU Ecolabel criteria for AHPs. The results are not intended to define thresholds, but to find hotspots that the criteria should focus on. It should be noted that only data on open baby diapers was received, and thus used in the assessment, although EU Ecolabel criteria includes all types of diapers, i.e. also pant diapers. There are no PEFCRs for absorbent hygiene products, thus this study is performed as a screening study following general PEF methodology rules defined in Zampori & Pant (2019). The study is not intended to define PEF category rules for AHPs.

The study is targeted at all the stakeholders who are following or involved in the revision of the EU Ecolabel criteria for AHPs, namely AHP EU Ecolabel applicants and other manufacturers, suppliers of AHP materials, competent bodies, NGOs, the EU Ecolabel board and other EU Commission services.

4.4.3.3 Scope of the study

4.4.3.3.1 Functional unit and reference flow

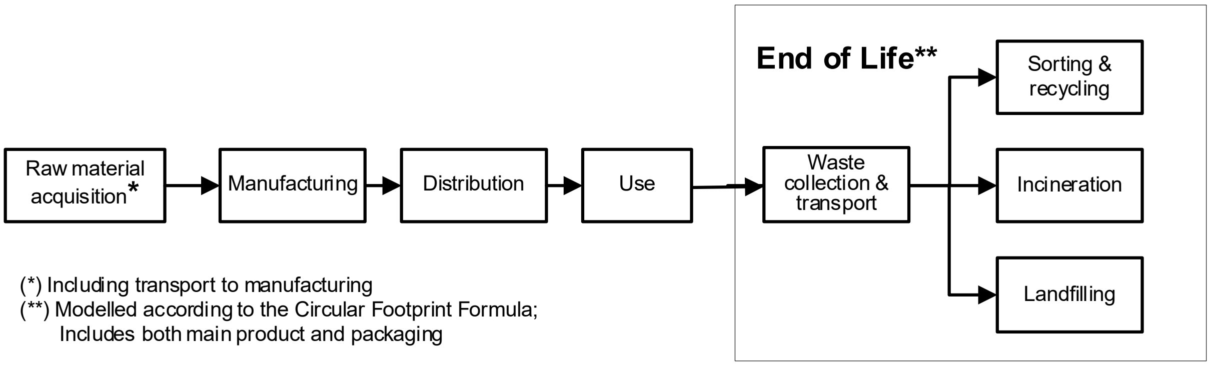
The functional unit of the study is one piece of the average product marketed in the European Union. The average product is defined using the average composition of the products from companies providing data, i.e. four baby diaper manufacturing companies and three sanitary towel manufacturing companies, without taking into account their absorbent capacity (not known). In particular, the functional units are as follows:

- An average open baby diaper based on data from four manufacturing companies.
- An average sanitary towel based on data from three manufacturing companies.

4.4.3.3.2 System boundary

The system boundary includes all life cycle stages from the raw material acquisition to the EoL (**Figure 29**). Raw material acquisition includes production of raw materials used in the product manufacturing, production of packaging, and their transportation to the manufacturing site. The manufacturing stage includes energy and other inputs used in the AHP manufacturing process, and treatment of scraps from the manufacturing process. Distribution includes transportation of the product from the manufacturing site to the retail and end user. The use phase was assumed to have zero burdens, as the product is ready to use and disposed of after use. The EoL phase includes the EoL of both the main product and packaging, but the EoL of faeces was excluded (i.e. increased mass to transport diapers and sanitary towels to EoL processes and impacts of landfill or incineration of faeces). Retail was assumed to have only small impacts in the AHP life cycle, and to be similar for all AHPs, thus retail was excluded from the assessment.

Figure 29. System boundary of absorbent hygiene products



Source: JRC.

4.4.3.4 Environmental Footprint impact categories

The EF 3.0 method, as implemented in the SimaPro 9.1 software, was used in the study. A list of impact categories with the respective impact category indicators, units and impact assessment models is presented in **Table 22**.

Table 22. Impact categories with respective impact category indicators, units and impact assessment models used in the assessment

Impact Category	**Impact Category indicator**	**Unit**	**Impact Assessment Model**
Climate Change, total (1)	Radiative forcing as Global Warming Potential (GWP_{100})	kg CO_2 eq	Baseline model of the IPCC over a 100-year time horizon (IPCC, 2013)
Ozone Depletion	Increase of stratospheric ozone breakdown as Ozone Depletion Potential (ODP)	kg CFC-11 eq	Steady-state model of the World Meteorological Organization over an infinite time horizon (WMO, 2014 + integrations)
Human Toxicity – cancer	Comparative Toxic Unit for humans (CTU_h)	CTU_h	USEtox model 2.1 (Fankte et al., 2017)
Human Toxicity – non-cancer	Comparative Toxic Unit for humans (CTU_h)	CTU_h	USEtox model 2.1 (Fankte et al., 2017)
Particulate Matter	Impact on human health	Disease incidence	PM method recommended by UNEP (UNEP, 2016)
Ionising Radiation – human health	Human exposure efficiency relative to U^{235}	kBq U^{235} eq	Human Health effect model (Dreicer et al., 1995)
Photochemical Ozone Formation - human health	Tropospheric ozone concentration increase	kg NMVOC eq	LOTOS-EUROS model (Van Zelm et al., 2008) as implemented in ReCiPe 2008
Acidification	Accumulated Exceedance (AE) of the critical load	mol H^+ eq	Accumulated Exceedance model (Seppälä et al., 2006; Posch et al., 2008)
Eutrophication – terrestrial	Accumulated Exceedance (AE) of the critical load	mol N eq	Accumulated Exceedance model (Seppälä et al., 2006; Posch et al., 2008)
Eutrophication – freshwater	Fraction of nutrients (P) reaching freshwater end compartment	kg P eq	EUTREND model (Struijs et al., 2009) as implemented in ReCiPe
Eutrophication – marine	Fraction of nutrients (N) reaching marine end compartment	kg N eq	EUTREND model (Struijs et al., 2009) as implemented in ReCiPe
Ecotoxicity –freshwater	Comparative Toxic Unit for ecosystems (CTUe)	CTUe	USEtox model 2.1 (Fankte et al, 2017)
Land Use	• Soil quality index (2) • Biotic production • Erosion resistance • Mechanical filtration • Groundwater replenishment	• Dimension less (pt) • kg biotic production • kg soil • m^3 water • m^3 ground-water	Soil quality index based on LANCA (Beck et al., 2010 and Bos et al., 2016)

Impact Category	Impact Category indicator	Unit	Impact Assessment Model
Water Use	User deprivation potential (deprivation-weighted water consumption)	m^3 world eq	Available WAter REmaining (AWARE) as recommended by UNEP, 2016
Resource use – minerals and metals	Abiotic resource depletion (ADP, based on ultimate reserves)	kg Sb eq	CML 2002 (Guinée et al., 2002) as updated in Van Oers et al. (2002)
Resource use – fossils	Abiotic resource depletion – fossil fuels (ADP-fossil)	MJ	CML 2002 (Guinée et al., 2002) and Van Oers et al. (2002)

(1) The indicator "Climate Change, total" consists of three sub-indicators: Climate Change – fossil; Climate Change – biogenic; and Climate Change – land use and land use change.

(2) This index is the result of the aggregation, performed by JRC, of the 4 indicators provided by the LANCA model as indicators for land use.

Source: JRC.

4.4.3.5 Additional environmental information

Biodiversity impacts are mainly related to raw material acquisition. In the case of AHPs, the raw materials are not known as typical high-biodiversity-impact materials, and thus biodiversity impacts are not assessed in this study.

4.4.3.5.1 Assumptions and limitations

The main assumptions in the modelling are related to transport distances and EoL, which are modelled according to the PEF method, using values and scenarios included in the method (Zampori & Pant, 2019). It was also assumed that storage and retail have only small impacts in the AHP life cycle, and that they are similar for all AHPs, thus these life cycle stages were excluded from the assessment.

The limitations of the study are related to data availability, more specifically as follows:

- Only the manufacturing process is based on primary data; all other data are secondary data from databases and literature, which affects the quality of the study.
- The EF database 2.0 was used due to the lack of EF 3.0 datasets and therefore secondary data are older. This affects the time representativeness of the secondary dataset.
- The average data of manufacturing of baby diapers is based only on four companies, and sanitary towels on three companies, without knowledge of / taking into account their market share. Also, there are different sizes of baby diapers for different age groups, and sanitary towels with different absorption capacities, but it was not specified in the data received which size they refer to. In addition, different manufacturers might use different raw materials, with higher or lower impacts, compared to the companies providing the data. Because of these issues, the conductor of the study cannot be sure how well the data used in the modelling represents the average products in Europe.
- Pant diapers were excluded from the study, and differences in product design compared to open diapers may lead to different results.
- The lack of primary data on relevant materials (i.e. SAP) and the use of a proxy dataset for adhesives increase the uncertainty on the results of the study.
- Baby diapers and sanitary towels can be considered lightweight materials, but, due to data on density or volume of the products, distribution was assumed to be mass limited.
- Potential impacts from additional washing of clothes because of possible leakage had insufficient data and are excluded from the assessment.
- Data on the absorption capacity of baby diapers and sanitary towels was not provided, thus the EoL impacts of faeces are not accounted for in the study, i.e. the increased weight of the product is not included in the transport of products to EoL processes, and neither are the incineration and landfilling

impacts of the faeces. However, the municipal waste incineration dataset takes into account the 34% humidity of the material; thus, energy credits from the waste incineration should not be overestimated.

4.4.3.6 Life-cycle inventory analysis

Included life-cycle stages are the following:

- raw material acquisition (including packaging production and transportation of raw materials and packaging);
- manufacturing of the product, including disposal of waste produced at the manufacturing site;
- distribution of the product from the manufacturing site to the retail and final user; and
- EoL (including both the main product and packaging).

A detailed description of the modelling choices of each life cycle stage are provided in the following sections. Storage and retail are assumed to have almost zero impact on the total life cycle, being similar for all AHPs, and these impacts are not included in the assessment. In addition, potential impacts from additional washing of clothes because of possible leakage are assumed to be small, and are excluded from the assessment. Capital goods are not otherwise included in the assessment, but in the case of use of EF and Ecoinvent datasets they are included.

4.4.3.6.1 Modelling choices

Modelling choices for raw material acquisition, manufacturing, distribution and EoL are explained as follows.

4.4.3.6.2 Raw material acquisition

For the modelling of the production of raw materials used in baby diaper and sanitary towel manufacturing, secondary data were used from the EF database 2.0, whenever available. In the event that a dataset was not available, Ecoinvent 3.6 (Wernet et al., 2016) was used as an alternative data source to model the impacts of that raw material, as described later. A list of raw materials used is presented in **Table 23**.

Table 23. List of raw materials used in the production of AHPs

Raw material	Dataset
Cellulose	Bleached kraft pulp softwood {US and CA} | production mix | at plant | per kg pulp (EF)*
SAP	Not available (see **Table 24**)
Polyethylene (PE)**	LDPE granulates {EU-28+EFTA} | Polymerisation of ethylene | production mix at plant | 0.91- 0.96 g/cm^3 28 g/mol per repeating unit (EF)
Polypropylene (PP)**	PP granulates {EU-28+EFTA} | Polymerisation of propene | production mix at plant | 0.91 g/cm^3 42.08 g/mol per repeating unit (EF)
Polyethyleneterephtalate (PET)**	PET amorphous {EU-28+EFTA} | Polymerisation of ethylene | production mix at plant | 0.91- 0.96 g/cm^3 28 g/mol per repeating unit (EF)
Adhesives	Dicyclopentadiene-based unsaturated polyester resin {RER} | production | APOS, S (EI)
Elastics	Ethylene propylene diene elastomer (EPDM) {World w/o EU-28+EFTA} | copolymerisation of ethylene and propylene | production mix at plant | 69% ethylene 38% propylene (EF)
Silicone paper	Silicone, low-viscosity {EU-28+EFTA} | hydrolysis and methanolysis of dimethyldichloro silane | production mix, at plant | <30 000 centipoise | LCI result (EF)
	Graphic paper {EU-28+3} | production mix | at plant | per kg graphic paper | LCI result (EF)
Viscose	Fibre, viscose {GLO}| fibre production, viscose | APOS, S (EI)

* EF = dataset from EF database, EI = dataset from Ecoinvent 3.6 database.

** Used as approximation for specialised absorbent materials.

*** Plastic granulate production process is complemented by the process: "Film Extrusion (blowing) {EU-28+EFTA} | plastic extrusion | production mix, at plant | for PP, PE, PVC, PET and PS".

Source: JRC.

SAP was modelled according to the production process for sodium polyacrylate documented in the US patent[42]. **Table 24** reports the input data and datasets used in the modelling.

Table 24. Summary of the input data and datasets used for SAP modelling

Raw material	Quantity (per kg SAP)	Unit	EF Dataset
Acrylic acid	319	g	Acrylic acid production {RER} | technology mix | production mix
Sodium hydroxide	354	g	Sodium hydroxide production {RER} | technology mix | production mix
Ethylene glycol	6.38	g	Ethylene glycol production {RER} | technology mix | production mix
Sodium persulphate	1.7	g	Sodium persulphate production {GLO} | technology mix | production mix
Zinc acetate*	319	g	
- Zinc oxide	140	g	Zinc oxide production {RER} | technology mix | production mix to consumer | 1kV - 60kV | LCI result
- Acetic acid	209	g	Acetic acid production {RER} | technology mix | production mix
Water	5.01	kg	Tap water {EU-28+3} | technology mix | at user | per kg water | LCI result
Electricity	7.8	MJ	Residual grid mix {EU-28+3} | AC technology mix | consumption

[42] https://patents.google.com/patent/US4295987A/en

Raw material	Quantity (per kg SAP)	Unit	EF Dataset
			mix

*The quantity of the chemicals needed to obtain zinc acetate is more than the quantity of zinc acetate due to the stoichiometry of the reaction.

Source: JRC.

All raw materials are assumed to come from Europe, except fluff pulp used for baby diapers which is assumed to be transported from the US. For European raw materials, the EF default scenario from supplier to factory was used:

- 130 km by truck;
- 240 km by train;
- 270 km by barge.

For fluff pulp from the US, the EF transport scenario for suppliers located outside Europe was used:

- 1000 km by truck (between factory and harbour, EF default);
- 10 000 km by transatlantic ship (according to distance from the US to Europe);

Both baby diapers and sanitary towels include similar primary and secondary packaging, i.e. polyethylene wrap and bag, and cardboard box. Raw materials and datasets used for packaging modelling are presented in **Table 25**. Packaging production was assumed to take place in Europe, with the following EF transport scenario for packaging materials:

- 230 km by truck;
- 280 km by train;
- 360 km by barge.

Table 25. List of packaging materials and datasets used for packaging modelling

Material	EF dataset
Polyethylene (PE)*	LDPE granulates {EU-28+EFTA} | Polymerisation of ethylene | production mix at plant | 0.91- 0.96 g/cm^3 28 g/mol per repeating unit
Cardboard box	Corrugated board, uncoated {EU-28+EFTA} | Kraft Pulping Process, pulp pressing and drying | production mix, at plant | flute thickness 0.8 - 2.8 mm, R1=88% | LCI result

*Plastic granulate production process is complemented by the process: "Film Extrusion (blowing) {EU-28+EFTA} | plastic extrusion | production mix, at plant | for PP, PE, PVC, PET and PS".

Source: JRC.

4.4.3.6.3 Manufacturing

Manufacturing of baby diapers and sanitary towels is a dry process; thus, only electricity is needed, in addition to raw materials. According to data collected from industries, the electricity used in the manufacturing is 100% renewable. Taking into account that manufacturing data were based on only a limited number of industries, a sensitivity analysis was performed to see the impact of electricity choice (Section 7). The average renewable energy mix for Europe was built using EUROSTAT data for the year 2019 (Eurostat 2021). **Table 26** reports the composition of EU average renewable electricity mix and datasets used in the modelling.

No outputs, beside the main product, were reported on the data collection form; however, it is acknowledged that during the production process some pieces are discarded on the manufacturing line due to errors in the process. To account for this, the figure from Cordella et al. (2015) of 4% scrapped product is used. This percentage is applied only to the product without packaging, since the hypothesis is that the pieces are discarded before the application of primary and secondary packaging. This waste material is treated with a worst-case scenario as municipal solid waste, similarly to the EoL of the whole product, although it is not the actual practice in manufacturing companies. Details of this scenario can be found in Section 4.1.4. In addition, this amount was added to the raw materials needed for production including the same origin and transportation distances as reported in Section 4.1.1.

Table 26. Composition of the EU renewable electricity mix

Electricity source	Share	EF Dataset
Wind	39%	Electricity from wind power {EU-28+3} | AC technology mix of onshore and offshore | production mix at plant | 1 - 60 kV
Hydro	32%	Electricity from hydro power {EU-28+3} | AC technology mix of run-off-river storage and pump storage | production mix at power plant | 1 - 60 kV
Solar	14%	Electricity from photovoltaic {FR} | AC technology mix of CIS CdTE mono-crystalline and multi-crystalline | production mix at plant | 1 - 60 kV
Solid biomass	10%	Electricity from biomass (solid) {EU-28+3} | AC mix of direct and CHP technology mix regarding firing and flue gas cleaning | production mix at power plant | 1 - 60 kV
Gaseous biomass	6%	Electricity from biogas {EU-28+3} | AC mix of direct and CHP technology mix regarding firing and flue gas cleaning | production mix at power plant | 1 - 60 kV
Geothermal	1%	Electricity from geothermal {IT} | AC CHP technology mix | production mix at power plant | 1 - 60 kV

Source: JRC.

4.4.3.6.4 Distribution

Distribution from the manufacturing site to the final client is modelled considering the default transport scenario in the PEF method (Zampori & Pant, 2019). The products are first transported to retail stores and from there to the final client. The underlying hypothesis is that 100% of the products are marketed via retail stores, and all the products are produced in Europe; therefore, the EF scenario of a local supply chain is used as follows: the transport from the factory to the retail is done with a truck, while for the transport from retail to final client 5% of the products are considered to be delivered by van, 62% by car, and the remaining 33% is considered to be without impacts, i.e. on foot, bike or other human-powered transport. The car travel is representative of the consumer travel to a retail shop (e.g. a supermarket); hence the 5 km are allocated to the product proportionally to its weight, considering an average shop of 10 kg. This assumption was made by the authors due to the lack of data; however, its influence on the final results is negligible. A summary of datasets and transport distances per unit of product is presented in **Table 27**.

Table 27. Summary of the mode of transport, distance and dataset used to model the distribution of products

Mode of transport	Share of products transported	Distance	EF Dataset
Truck from factory to retail	100%	1200 km	Articulated lorry transport, Euro 4, Total weight >32 t (with fuel) {EU-28+3} | diesel driven, Euro 4, cargo | consumption mix, to consumer | more than 32 t gross weight / 24.7t payload capacity | Unit process, single operation
Car from retail store to final client	62%	5 km	Passenger car, average {GLO} | technology mix, gasoline and diesel driven, Euro 3-5, passenger car | consumption mix, to consumer | engine size from 1.4 l up to >2 l | LCI result
Van from retail store to final client	5%	5 km	§ Articulated lorry transport, Euro 3, Total weight <7.5 t (with fuel) {EU-28+3} | diesel driven, Euro 3, cargo | consumption mix, to consumer | up to 7.5 t gross weight / 3.3 t payload capacity | Unit process, single operation

Source: JRC.

4.4.3.6.5 End-of-Life

The EoL of the products was modelled using the Circular Footprint Formula (CFF) and considering separate scenarios for the EoL of the product and its packaging. The parameters used in the CFF are as follows:

- R1 is the share of recycled content in the raw materials. This parameter has been considered to be 0 due to the lack of data on the supply chain of materials. The only exception is cardboard used for the packaging, which according to the EF dataset used has a recycled content of 88%.
- R2 is the share of materials sent to recovery at the EoL of the product. For the disposal of the product this is considered to be 0 as the AHPs at the end of their life cannot be recovered. For the packaging, Annex C in the PEF method (Zampori & Pant, 2019) provides the average value of R2 in the European market.
- R3 is the share of material sent to energy recovery. For the product the average value of R3 for municipal solid waste was used (45%, from Annex C in the PEF method (Zampori & Pant, 2019)). For packaging, the share was calculated considering the share of packaging not recovered (1-R2) and considering it as MSW (45%*(1-R2)).
- A is the allocation factor of environmental burdens between the supplier and user of recycled material. Lower values allocate more burden on the waste producer. The values are suggested in Annex C of the PEF method (Zampori & Pant, 2019) and they are based on an extensive evaluation performed during the development of the pilot-phase PEFCRs.
- Qsout/Qp represents the different quality of the secondary material produced in the recycling process compared to the quality of the virgin material.

The values reported in **Table 28** were retrieved from the latest version of Annex C of the PEF method (Zampori & Pant, 2019), except the R2 value for PE packaging, which is based on the recycled amount of PE packaging from households in the EU (Eunomia, 2020). The table also reports the dataset used for landilling (E_D), incineration with energy recovery (E_R) and recycling at the EoL ($E_{recyclingEoL}$). For the recycling of PE a proxy dataset for PP in the US has been used, while for cardboard a custom dataset was created using data on energy consumption in cardboard production from Ecoinvent 3.6 (Wernet et al., 2016).

Table 28. Summary of the Circular Footprint Formula parameters used in the end-of-life modelling

Material	A	R1	R2	R3	Qsout/ Qp	Dataset used
Main product (municipal solid waste)	-	0%	0%	45%	-	**E_R** including credits from electricity and heat recovery: Waste incineration of municipal solid waste {EU-28+EFTA} | waste-to-energy plant with dry flue gas treatment including transport and pre-treatment | production mix at consumer | municipal solid waste
						E_D: Landfill of municipal solid waste {EU-28+EFTA}
PE packaging	0.5	0%	17%	14%	0.75	**E_R** including credits from electricity and heat recovery: Waste incineration of plastics (unspecified) {EU-28+EFTA} | waste-to-energy plant with dry flue gas treatment including transport and pre-treatment | production mix
						E_D: Landfill of plastic waste {EU-28+EFTA} | landfill including leachate treatment and with transport without collection and pre-treatment | production mix (region specific sites) at landfill site
						$E_{recyclingEoL}$: Recycling of polypropylene (PP) plastics {US} | from post-consumer waste via washing, granulation, pelletisation | production mix at plant | 90% of recycling rate
Cardboard packaging	0.2	88%	75%	14%	0.85	**E_R** including credits from electricity and heat recovery: Waste incineration of paper and board {EU-28+EFTA} | waste-to-energy plant with dry flue gas treatment including transport and pre-treatment | production mix at consumer | paper waste
						E_D: Landfill of paper and paperboard waste {EU-28+EFTA}
						$E_{recyclingEoL}$: custom dataset* including: 0.16 kWh/kg of "Residual grid mix {EU-28+3} | AC, technology mix | consumption mix, to consumer | 1 - 60 kV | LCI result" 0.51 kJ/kg of "Thermal energy from natural gas {EU-28+3} | technology mix regarding firing and flue gas cleaning | production mix, at heat plant | MJ, 100% efficiency | LCI result"

* The quantity of energy used for the dataset was retrieved from the dataset "Containerboard, linerboard {RER} containerboard production, linerboard, testliner | APOS" of Ecoinvent 3.6 (Wernet et al., 2016).

Source: JRC.

4.4.3.7 Modelling multi-functional processes

There are no multifunctional processes. The only multifunctional processes are present in the background datasets and are assessed using the PEF method.

4.4.3.8 Data collection

Data on bills of materials and on inputs and outputs at the manufacturing stage was collected from companies manufacturing baby diapers and sanitary towels. EDANA collected data from their member companies using a data collection form provided by the JRC. Manufacturing data were received from four companies producing open baby diapers and three companies producing sanitary towels. According to the data from individual companies, EDANA calculated arithmetic mean data for the JRC, without taking into account the market shares of the companies. Data collected from companies are classified as confidential and cannot be published.

4.4.3.9 Data quality requirements and rating

The Data Quality Rating (DQR) of the two products was assessed using the criteria described in the PEF methodology. The most relevant processes (i.e. the ones accounting for more than 80% of the overall impact) were included in the rating.

The data quality assessment uses four criteria that are scored independently from 1 to 5, with 1 being the highest score. The criteria are precision (P), time representativeness (TiR), geographical representativeness (GeR) and technological representativeness (TeR). Then, the score of each dataset is weighted, according to its share of impact, to give the final Data Quality Rating. The Data Quality Rating is presented in **Table 29** (baby diapers) and **Table 30** (sanitary towels).

The final result is a good Data Quality Level (score 2.04) for baby diapers, and a very good one (score 1.66) for sanitary towels. Although the score for both baby diapers and sanitary towels is good, it can be noticed that while the geographical and technological representativeness of the dataset is high (<3), the precision and time representativeness have lower scores. This is due to the nature of the study which used data from the manufacturing companies although most of the relevant processes are beyond the control of these companies.

Table 29. Data Quality Rating of open baby diapers

Dataset	Weight	TeR	GeR	TiR	P	DQR
Baby diaper						**2.04**
SAP production	27.1%	2	2	4	3	2.75
Freight train, average (with fuel) {EU-28+3} | technology mix, electricity and diesel driven, cargo | consumption mix, to consumer | average train, gross tonne weight 1000 t / 726 t payload capacity | Unit process, single operation	16.5%	1	1	3	4	2.25
PP granulates {EU-28+EFTA} | polymerisation of propene | production mix, at plant | 0.91 g/cm^3, 42.08 g/mol per repeating unit | LCI result	13.6%	1	1	1	3	1.5
Bleached kraft pulp, softwood {US and CA} | production mix | at plant | per kg pulp | LCI result	8.4%	1	1	1	3	1.5
LDPE granulates {EU-28+EFTA} | Polymerisation of ethylene | production mix, at plant | 0.91 - 0.96 g/cm^3, 28 g/mol per repeating unit | LCI result (main product)	5.9%	1	1	1	3	1.5
Landfill of municipal solid waste {EU-28+EFTA} | LCI result	5.7%	1	1	4	4	2.5
Dicyclopentadiene-based unsaturated polyester resin {RER}| production | APOS, S	4.2%	2	1	1	3	1.75
PET granulates, amorphous {EU-28+EFTA} | Polymerisation of ethylene | production mix, at plant | 0.91 - 0.96 g/cm^3, 28 g/mol per repeating unit | LCI result	4.0%	1	1	1	3	1.5
Ethylene propylene diene elastomer (EPDM) {World w/o EU-28+EFTA} | copolymerisation of ethylene and propylene | production mix, at plant | 69% ethylene, 38% propylene | LCI result	3.0%	1	1	1	3	1.5
Transatlantic ship, containers {GLO} | heavy fuel oil driven, cargo | consumption mix, to consumer | 27 500 dwt payload capacity, ocean going | LCI result	2.4%	1	1	3	4	2.25
Articulated lorry transport, Euro 4, Total weight >32 t (with fuel) {EU-28+3} | diesel driven, Euro 4, cargo | consumption mix, to consumer | more than 32 t gross weight / 24.7 t payload capacity | Unit process, single operation	2.2%	1	1	3	4	2.25
Film Extrusion (blowing) {EU-28+EFTA} | plastic extrusion | production mix, at plant | for PP, PE, PVC, PET and PS | LCI result	2.1%	1	1	1	3	1.5
LDPE granulates {EU-28+EFTA} | Polymerisation of ethylene | production mix, at plant | 0.91- 0.96 g/cm^3, 28 g/mol per repeating unit | LCI result (packaging)	1.5%	1	1	1	3	1.5
Passenger car, average {GLO} | technology mix, gasoline and diesel driven, Euro 3-5, passenger car | consumption mix, to consumer | engine size from 1.4 l up to >2 l | LCI result	1.3%	1	1	3	4	2.25

Source: JRC.

Table 30. Data Quality Rating of sanitary towels

Dataset	Weight	TeR	GeR	TiR	P	DQR
Sanitary towel						**1.66**
Freight train, average (with fuel) {EU-28+3} | technology mix, electricity and diesel driven, cargo | consumption mix, to consumer | average train, gross tonne weight 1000 t / 726 t payload capacity | Unit process, single operation	19.0%	1	1	3	4	2.25
PET granulates, amorphous {EU-28+EFTA} | Polymerisation of ethylene | production mix, at plant | 0.91 - 0.96 g/cm^3, 28 g/mol per repeating unit | LCI result	15.2%	1	1	1	3	1.5
LDPE granulates {EU-28+EFTA} | Polymerisation of ethylene | production mix, at plant | 0.91- 0.96 g/cm^3, 28 g/mol per repeating unit | LCI result (main product)	13.2%	1	1	1	3	1.5
Fibre, viscose {GLO}| fibre production, viscose | APOS, S	12.9%	1	1	1	3	1.5
LDPE granulates {EU-28+EFTA} | Polymerisation of ethylene | production mix, at plant | 0.91 - 0.96 g/cm^3, 28 g/mol per repeating unit | LCI result (packaging)	8.1%	1	1	1	3	1.5
Bleached kraft pulp, softwood {EU-28+3} | production mix | at plant | per kg pulp | LCI result	7.4%	1	1	1	3	1.5
Dicyclopentadiene-based unsaturated polyester resin {RER}| production | APOS, S	4.4%	2	1	1	3	1.75
PP granulates {EU-28+EFTA} | polymerisation of propene | production mix, at plant | 0.91 g/cm^3, 42.08 g/mol per repeating unit | LCI result	4.3%	1	1	1	3	1.5
SAP production	3.1%	2	2	4	3	2.75
Silicone, low-viscosity {EU-28+EFTA} | hydrolysis and methanolysis of dimethyldichloro silane | production mix, at plant | <30 000 centipoise | LCI result	2.6%	1	1	1	3	1.5
Film Extrusion (blowing) {EU-28+EFTA} | plastic extrusion | production mix, at plant | for PP, PE, PVC, PET and PS | LCI result	2.6%	1	1	1	3	1.5
Articulated lorry transport, Euro 4, Total weight >32 t (with fuel) {EU-28+3} | diesel driven, Euro 4, cargo | consumption mix, to consumer | more than 32 t gross weight / 24.7 t payload capacity | Unit process, single operation	2.0%	1	1	3	4	2.25
Passenger car, average {GLO} | technology mix, gasoline and diesel driven, Euro 3-5, passenger car | consumption mix, to consumer | engine size from 1.4 l up to >2 l | LCI result	1.2%	1	1	3	4	2.25

Source: JRC.

4.4.3.10 Impact assessment results

Tables Table 31 and **Source:** *JRC.*

Table 32 present characterised, normalised and weighted results of open baby diapers and sanitary towels, respectively. Characterised results are presented per life cycle stage, and Climate Change subcategories are reported separately. As there are not additional environmental burdens added to the system at the use stage results are excluded from the tables.

Table 31. Characterised, normalised and weighted impacts of open baby diapers

Impact category	Characterised impact					Normalised impact	Weighted impact
	Raw material acquisition	Manufacturing	Distribution	End-of-Life	Total		
Climate Change [kg CO_2 eq.]	6.80E-02	1.39E-03	3.89E-03	1.68E-02	9.00E-02	1.11E-05	2.34E-06
				Climate Change (fossil) [kg CO_2 eq.]	7.33E-02	-	-
				Climate Change (biogenic) [kg CO_2 eq.]	1.67E-02	-	-
				Climate Change (land use and land use change) [kg CO_2 eq.]	6.84E-05	-	-
Ozone Depletion [kg CFC-11 eq.]	3.46E-09	-7.15E-15	8.71E-15	-9.25E-13	3.46E-09	6.45E-08	4.07E-09
Ionising Radiation [kBq U^{235} eq.]	1.09E-02	-1.42E-05	8.86E-06	-1.14E-03	9.71E-03	2.30E-06	1.15E-07
Photochemical Ozone Formation [kg NMVOC eq.]	5.65E-04	6.00E-06	1.64E-05	4.60E-06	5.92E-04	1.46E-05	6.97E-07
Particulate matter [Disease incidence]	5.11E-09	8.20E-11	2.90E-10	-9.83E-11	5.39E-09	9.05E-06	8.11E-07
Human toxicity - non-cancer [CTUh]	8.93E-10	3.98E-11	1.95E-11	9.00E-11	1.04E-09	4.54E-06	8.35E-08
Human Toxicity - cancer [CTUh]	1.01E-10	7.58E-13	7.78E-13	-3.01E-13	1.02E-10	6.03E-06	1.28E-07
Acidification [mol of H^+ eq.]	4.97E-04	7.61E-06	4.66E-05	-7.14E-06	5.44E-04	9.80E-06	6.07E-07
Eutrophication - freshwater [kg P eq.]	3.41E-06	8.78E-08	1.01E-08	3.43E-07	3.85E-06	2.40E-06	6.72E-08
Eutrophication - marine [kg N eq.]	1.81E-04	2.86E-06	8.78E-06	3.27E-06	1.96E-04	1.00E-05	2.97E-07
Eutrophication - terrestrial [mol N eq.]	1.98E-03	2.50E-05	2.15E-04	1.19E-05	2.23E-03	1.26E-05	4.69E-07
Ecotoxicity - freshwater [CTUe]	8.17E-01	5.48E-02	4.52E-02	-1.72E-03	9.15E-01	2.14E-05	4.12E-07
Land Use [Pt]	2.89E+00	1.08E-01	3.62E-03	-3.47E-01	2.65E+00	3.24E-06	2.57E-07
Water Use [m^3 world eq.]	4.60E-02	3.65E-03	2.81E-04	-6.20E-04	4.93E-02	4.30E-06	3.66E-07
Resource Use - fossils [MJ]	1.64E+00	2.32E-03	5.39E-02	-8.63E-02	1.61E+00	2.48E-05	2.06E-06
Resource Use - mineral and metals [kg Sb eq.]	3.71E-07	1.57E-08	2.01E-10	-1.05E-09	3.86E-07	6.06E-06	4.58E-07

Source: JRC.

Table 32. Characterised, normalised and weighted impacts of sanitary towels. *Source: JRC.*

Impact category	**Characterised impact**					**Normalised impact**	**Weighted impact**
	Raw material acquisition	**Manufacturing**	**Distribution**	**End-of-Life**	**Total**		
Climate Change [kg CO_2 eq.]	1.45E-02	2.35E-04	1.06E-03	-1.30E-04	1.56E-02	1.93E-06	4.06E-07
				Climate Change (fossil) [kg CO_2 eq.]	1.50E-02	-	-
				Climate Change (biogenic) [kg CO_2 eq.]	6.12E-04	-	-
				Climate Change (land use and land use change) [kg CO_2 eq.]	1.92E-05	-	-
Ozone Depletion [kg CFC-11 eq.]	6.08E-10	-4.16E-15	2.37E-15	-8.21E-14	6.08E-10	1.13E-08	7.15E-10
Ionising Radiation [kBq U^{235} eq.]	1.62E-03	-6.01E-06	2.43E-06	-9.55E-05	1.42E-03	3.36E-07	1.68E-08
Photochemical Ozone Formation [kg NMVOC eq.]	1.71E-04	9.45E-07	4.67E-06	-3.77E-06	1.73E-04	4.25E-06	2.03E-07
Particulate matter [Disease incidence]	1.44E-09	1.24E-11	9.38E-11	-3.45E-11	1.51E-09	2.53E-06	2.27E-07
Human toxicity - non-cancer [CTUh]	4.51E-10	6.37E-12	5.23E-12	-7.90E-12	4.54E-10	1.98E-06	3.64E-08
Human Toxicity - cancer [CTUh]	6.21E-11	1.18E-13	2.08E-13	-1.32E-12	6.11E-11	3.62E-06	7.70E-08
Acidification [mol of H^+ eq.]	1.39E-04	1.16E-06	1.48E-05	-3.62E-06	1.51E-04	2.73E-06	1.69E-07
Eutrophication - freshwater [kg P eq.]	1.20E-06	1.40E-08	2.60E-09	-4.01E-09	3.45E-07	2.15E-07	6.01E-09
Eutrophication - marine [kg N eq.]	5.45E-05	4.51E-07	2.56E-06	-1.12E-06	5.62E-05	2.87E-06	8.51E-08
Eutrophication - terrestrial [mol N eq.]	5.92E-04	3.95E-06	6.85E-05	-1.05E-05	6.54E-04	3.70E-06	1.37E-07
Ecotoxicity - freshwater [CTUe]	2.62E-01	8.43E-03	1.24E-02	-5.80E-03	2.77E-01	6.49E-06	1.25E-07
Land Use [Pt]	1.12E+00	1.67E-02	9.36E-04	-1.82E-01	9.54E-01	1.16E-06	9.24E-08
Water Use [m^3 world eq.]	1.43E-02	5.66E-04	7.37E-05	-5.16E-04	1.44E-02	1.26E-06	1.07E-07
Resource Use - fossils [MJ]	3.69E-01	5.18E-05	1.47E-02	-1.58E-02	3.68E-01	5.66E-06	4.71E-07
Resource Use - mineral and metals [kg Sb eq.]	4.38E-07	2.43E-09	5.37E-11	-3.79E-10	4.40E-07	6.92E-06	5.22E-07

4.4.3.11 Interpretation of results

The most relevant impact categories, life-cycle stages, processes and flows are presented in **Table 33** (baby diapers) and **Table 34** (sanitary towels). In these tables, the contribution of each impact category was calculated based on the normalised and weighted impacts, whereas characterised results were used to identify the most relevant life-cycle stages, processes and elementary flows. The respective contribution (in %) for each of the life-cycle stages, processes and elementary flows refers to the individual contribution for a specific impact category. Negative values were kept as negative to be able to see benefits from EoL, although the PEF method suggests using absolute values.

For baby diapers, Climate Change is the most relevant impact category with a 26% share, followed by Resource Use – fossils (23%), Particulate Matter (9%), Photochemical Ozone Formation (8%), Acidification (7%), Eutrophication – terrestrial (5%) and Resource Use – minerals and metals (5%). When comparing the results with other studies, the most relevant impact categories for disposable baby diapers are Eutrophication Potential, Climate Change and Primary Energy Demand (Mendoza et al., 2019). Hoffman et al. (2020) also concluded that Climate Change is the most contributing impact category for disposable baby diapers.

For sanitary towels the most relevant impact category is Resource Use – Minerals and metals with a 19% share, followed by Resource Use – fossils (17%), Climate Change (15%), Particulate Matter (8%), Photochemical Ozone Formation (7.5%), Acidification (6%), Eutrophication - terrestrial (5%) and Ecotoxicity - freshwater (5%).

Raw material acquisition is always the most relevant life cycle stage, having a contribution between 76% (Climate Change) and 102% (Resource Use - fossils) for baby diapers, and between 91% (Eutrophication, terrestrial) and 100% (Resource Use – fossils and Resource Use - minerals and metals) for sanitary towels. Resource Use – fossils exceeds 100% due to negative values in the EoL.

The most relevant processes related to raw material acquisition of the baby diaper include production of SAP, fluff pulp, and PP, LDPE and PET granulates (the complete list by impact categories and shares can be seen in **Table 33**). These raw materials are also the main raw materials in baby diaper production, especially SAP which was assumed to have a 40% share of the all raw materials, and are thus identified to have the highest contributions of the impacts. In addition to raw materials, waste landfilling (in Climate Change), train transportation of raw materials and packaging (in Particulate Matter, Photochemical Ozone Formation, Acidification and Eutrophication – terrestrial), ship transportation of fluff pulp from the US to Europe (in Particulate Matter and Photochemical Ozone Formation), and lorry transportation of raw materials and in the product distribution phase (in Particulate Matter, Acidification and Eutrophication – terrestrial) are also identified among the most relevant processes for baby diapers in some impact categories. The results obtained are in line with the overview of published LCA studies (Sections 4.4.1 and 4.4.2), as explained in the next paragraph.

The raw material acquisition is also the main contributing life-cycle stage in the Cordella et al. (2015) and Mendoza et al. (2019) studies. However, in the Hoffman et al. (2020) study, the EoL is the most contributing life cycle stage with a 75% contribution in the Climate Change impact category due to emissions from landfilling, which is also identified as a hotspot in this study, but with lower importance. It has to be noted that results cannot be fully compared because of the differences in the definition of the functional unit (FU) and different characterisation methods used in the different studies. For example, in Aumonier et al. (2008) the Climate Change impact is 568 kg CO_2 eq for 'one toilet trained child' or '4550 used diapers', while Hoffman et al. (2020) obtained an impact of 1236 kg CO_2 eq for the same functional unit. In Cordella et al. (2015) the overall CO_2 eq is 592 kg and in the present study the Climate Change impact is 410 kg CO_2 eq, or, if the impact is converted, as the use of 4550 diapers.

The most relevant processes related to raw material acquisition of the sanitary towel include production of viscose, fluff pulp, and PET, LDPE and PP granulates (the complete list by impact categories and shares can be seen in **Table 34**). Production of LDPE granulates and film extrusion of LDPE for packaging production were also identified among the most relevant processes in some impact categories, mainly in Resource Use – fossils (17%), Climate Change (11% granulates, 6% extrusion) and Ecotoxicity – freshwater (14%). In the case of sanitary towels, LDPE packaging has a higher contribution in the most relevant processes compared to baby diapers because of the higher share of packaging materials compared to the product mass in sanitary towels. This also explains the presence of an additional impact category (Ecotoxicity – freshwater) in the group of the most relevant ones for sanitary towels and the difference in the ranking of the other six. In addition to the raw materials and packaging production, train transportation of raw materials and packaging and lorry transportation of raw materials and in the product distribution phase are also identified among the most relevant processes for sanitary towels in some impact categories. In contrast to baby diapers, waste landfilling was not identified among the most relevant processes, because of the smaller mass of the product compared to LDPE packaging, when the credits from packaging recycling compensate the emissions from the landfilling.

When comparing the results with other studies, Mazgaj at al. (2021) observed that the most contributing process in sanitary towels is the production of the LDPE foil, while Hait and Powers (2019) and Vilabrille Paz et al. (2020) (as cited in the United Nations Environment Programme report, UNEP (2021)) found that manufacturing of raw materials contributed the most to the overall impact. According to Hait and Powers (2019), the most contributing raw materials in sanitary towel manufacturing are polyethylene (66% of Energy Resource Use and 34% of the Climate Change impact), and absorbent fluff from softwood pulp (23% of the Climate Change impact).

Distribution typically has contributions around 5%, but in Acidification and Eutrophication – terrestrial it is around 10%. The high contribution of the transport during distribution is in all cases mainly due to the transportation of the product by lorry. In some impact categories, train transportation was identified among the most relevant processes, which is the part of raw material (240 km) and packaging (280 km) transportation scenario, which are taken from (Zampori & Pant, 2019). For baby diapers, train transportation has contributions of 46% (Particulate Matter), 58% (Photochemical Ozone Formation), 42% (Acidification), and 59% (Eutrophication - terrestrial), and is the most relevant process in those impact categories. For sanitary towels, train transport has contributions of 56% (Particulate Matter), 67% (Photochemical Ozone Formation), 51% (Acidification), and 68% (Eutrophication - terrestrial), and is again the most relevant process in those impact categories.

The Manufacturing and EoL stages have only a small share of impacts in almost all impact categories. Only in the Climate Change impact of baby diapers does EoL have a 19% contribution, because of emissions from the landfilling of the product. For sanitary towels, this is not the case because the mass of the packaging is relatively high compared to the mass of the product itself; thus, the credits received from the EoL of the packaging (assumed to be partly recycled) partly compensate the impacts of landfilling the product. The credits from the EoL of the packaging (assumed to be partly recycled) also explain why the EoL stage has a negative share in some impact categories, i.e. benefits from the EoL of the packaging outweigh the impacts of landfilling the main product.

It is worth noting that currently several countries in Europe such as the Netherlands (ARN/Elsinga)[43] or Italy (FATER)[44] offer options for partial recycling of baby diapers rather than incineration or landfill disposal as has been considered in the PEF modelling with SimaPro for this study. As recycling is not yet available in the majority of EU countries this option was not explored in the present study. Generally, used baby diapers are disposed of within MSW (Municipal Solid Waste) and sent to landfill or incineration without further recovery. As more countries are expected to set alternative recovery of used absorbent hygiene products, the recyclability could then be explored in future scenarios concerning the impacts of AHPs. However, the management and final disposal of used AHPs are outside the scope of the EU Ecolabel criteria. The EU Ecolabel could encourage recycling once each waste management system has established the possibility at the national level of the Member States.

[43] Comparative mLCA on waste treatment of diaper and incontinence material Revised. Commissioned by Rijkswaterstaat Water, Verkeer & Leefomgeving (WVL). 2021. Available at: https://lap3.nl/publish/pages/138145/2021-02-24-vergelijkende-mlca-luier-afvalverwerking-herzien.pdf

[44] Khoo, S. C., Phang, X. Y., Ng, C. M., Lim, K. L., Lam, S. S. and Ma, N. L., 'Recent technologies for treatment and recycling of used disposable baby diapers', Process Safety and Environmental Protection, Vol. 123, Elsevier, 2019, pp. 116-129.

Table 33. The most relevant impact categories, life-cycle stages, processes and elementary flows of baby diapers

Most relevant impact category	[%]	Most relevant life-cycle stage	[%]	Most relevant processes	[%]	Most relevant elementary flows	[%]
Climate Change	**25.5%**	Raw material acquisition	76%	SAP production	35%	Carbon dioxide, fossil	72%
				Landfill of municipal solid waste	20%		
		End-of-Life	19%	PP granulates production	13%		
				Pulp production	6%		
		Distribution	4%	LDPE granulates production for the main product	5%	Methane, biogenic	19%
		Manufacturing	2%	Polyester resin production	4%		
Resource Use – fossils	**22.5%**	Raw material acquisition	102%	SAP production	39%	Energy, from oil	46%
		Distribution	3%	PP granulates production	29%	Energy, from gas, natural	28%
		Manufacturing	0%	LDPE granulates production for the main product	10%	Energy, from uranium	10%
		End-of-Life	-5%	Polyester resin production	6%		
Particulate Matter	**8.8%**	Raw material acquisition	95%	Transport, train	46%	Particulates, <2.5 μm	65%
				SAP production	19%		

Most relevant impact category	[%]	Most relevant life-cycle stage	[%]	Most relevant processes	[%]	Most relevant elementary flows	[%]
		Distribution	5%	Pulp production	7%		
		Manufacturing	2%	Transport, transoceanic ship	6%	Sulphur dioxide	16%
		End-of-Life	-2%	Transport, lorry	5%		
Photochemical Ozone Formation	**7.6%**	Raw material acquisition	95%	Transport, train	58%	Nitrogen dioxide	72%
				SAP production	10%		
		Distribution	3%	Pulp production	6%	NMVOC	11%
		Manufacturing	1%	PP granulates production	5%		
		End-of-Life	1%	Transport, transatlantic ship	5%		
Acidification	**6.6%**	Raw material acquisition	91%	Transport, train	42%	Nitrogen dioxide	58%
				SAP production	17%		
		Distribution	9%	Transport, lorry	8%	Sulphur dioxide	27%
		Manufacturing	1%	Transport, transoceanic ship	7%		

Most relevant impact category	[%]	Most relevant life-cycle stage	[%]	Most relevant processes	[%]	Most relevant elementary flows	[%]
		End-of-Life	-1%	Pulp production	6%		
Eutrophication - terrestrial	**5.1%**	Raw material acquisition	89%	Transport, train	59%	Nitrogen dioxide	82%
		Distribution	10%	Transport, lorry	9%		
		Manufacturing	1%	SAP production	8%		
		End-of-Life	1%	Bleached kraft pulp production	6%		
Resource Use – minerals and metals	**5.0%**	Raw material acquisition	96%	PET granulate production	59%	Antimony	59%
		Manufacturing	4%	SAP production	20%	Gold	21%
		Distribution	0%	Polyester resin production	12%	Copper	6%
		End-of-Life	0%				

Source: JRC.

Table 34. The most relevant impact categories, life-cycle stages, processes and elementary flows of sanitary towels

Most relevant impact category	[%]	Most relevant life-cycle stage	[%]	Most relevant processes	[%]	Most relevant elementary flows	[%]
Resource Use – minerals and metals	**19.4%**	Raw material acquisition	100%	PET granulates production	58%	Antimony	58%
		Manufacturing	1%				
		Distribution	0%	Viscose production	32%	Gold	35%
		End-of-Life	0%				
Resource Use - fossils	**17.4%**	Raw material acquisition	100%	LDPE granulates production for the main product	28%	Energy, from oil	48%
				LDPE granulates production for the packaging	17%		
		Distribution	4%	PP granulates production	12%	Energy, from gas, natural	26%
				PET granulates production	9%		
		Manufacturing	0%	Polyester resin production	8%	Energy, from uranium	6%
		End-of-Life	-4%	SAP production	6%		
Climate Change	**15.1%**	Raw material acquisition	93%	LDPE granulate production for the main product	18%	Carbon dioxide, fossil	84%
				LDPE granulate production for the packaging	11%		

Most relevant impact category	[%]	Most relevant life-cycle stage	[%]	Most relevant processes	[%]	Most relevant elementary flows	[%]
				Viscose production	11%		
		Distribution	7%	PET granulate production	8%		
				Pulp production	7%		
		Manufacturing	2%	PP granulate production	7%		
				Polyester resin production	7%		
		End-of-Life	-1%	SAP production	7%		
				Film extrusion of LDPE	6%		
Particulate Matter	**8.4%**	Raw material acquisition	95%	Transport, train	56%	Particulates, <2.5 µm	68%
				Viscose production	12%		
		Distribution	6%	Pulp production	5%	Nitrogen dioxide	13%
		Manufacturing	1%	Transport, lorry	4%		
		End-of-Life	-2%	LDPE granulates production for the main product	4%		

Most relevant impact category	[%]	Most relevant life-cycle stage	[%]	Most relevant processes	[%]	Most relevant elementary flows	[%]
Photochemical Ozone Formation	**7.5%**	Raw material acquisition	99%	Transport, train	67%	Nitrogen dioxide	71%
		Distribution	3%	LDPE granulates production for the main product	6%		
		Manufacturing	1%	Pulp production	6%	NMVOC	12%
		End-of-Life	-2%	Polyester resin production	4%		
Acidification	**6.3%**	Raw material acquisition	92%	Transport, train	51%	Nitrogen dioxide	60%
				Viscose production	10%		
		Distribution	10%	Transport, lorry	8%	Sulphur dioxide	23%
		Manufacturing	1%	Pulp production	6%		
		End-of-Life	-2%	LDPE granulates production for the main product	5%		
Eutrophication – terrestrial	**5.1%**	Raw material acquisition	91%	Transport, train	68%	Nitrogen dioxide	80%
		Distribution	10%	Transport. lorry	8%		

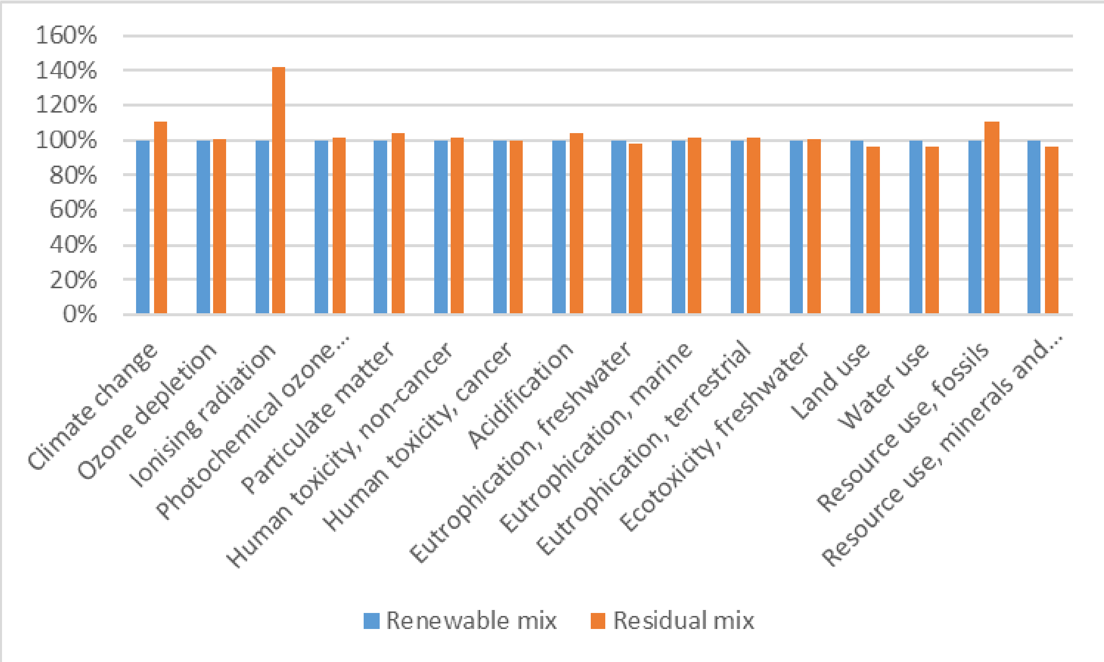
Most relevant impact category	[%]	Most relevant life-cycle stage	[%]	Most relevant processes	[%]	Most relevant elementary flows	[%]
		Manufacturing	1%	Pulp production	5%	Ammonia	8%
		End-of-Life	-2%				
Ecotoxicity – freshwater	**5.0%**	Raw material acquisition	95%	LDPE granulates production for the main product	23%	Chloride to water	59%
				Viscose production	21%		
		Distribution	4%	LDPE granulates production for the packaging	14%	Aluminium to air	12%
				PP granulate production	9%		
		Manufacturing	3%	PET granulate production	6%		
				Pulp production	6%	Aluminium to soil	9%
		End-of-Life	-2%	Polyester resin production	5%		

Source: JRC.

4.4.3.12 Sensitivity analysis

According to the data collected from industry, the electricity used during manufacturing is 100% renewable (Section 4.4.3.6.4 Manufacturing). Taking into account that manufacturing data were based on a limited amount of industries, a sensitivity analysis was performed to see the impact of the electricity choice. When the EF dataset 'Residual grid mix {EU-28+3} | AC, technology mix | consumption mix, to consumer | 1 - 60 kV', which represents the European average mix, was used instead of the 'EU renewable electricity mix', no significant differences could be appreciated in the results in the majority of the impact categories (see **Figure 30**). The difference is significant only for Ionising Radiation, due to the presence of nuclear energy in the average electricity mix (the 'residual grid mix' dataset). However, Ionising Radiation is not among the most relevant impact categories for this modelling, so the main conclusions would not change if a different electricity mix was used.

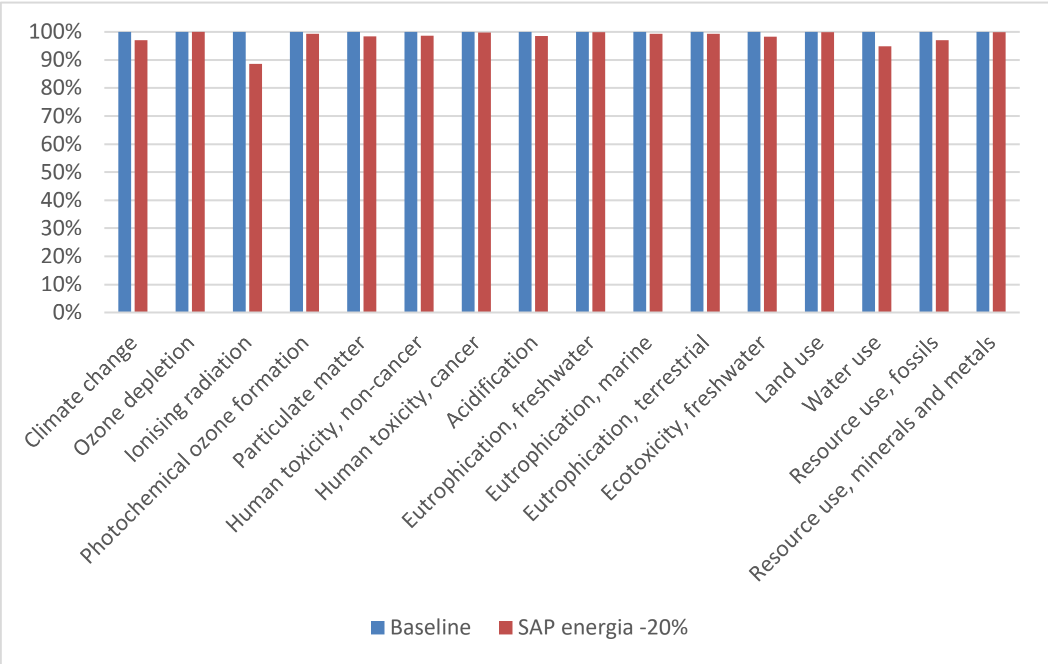
Figure 30. Comparison of baby diaper results when the electricity used in the manufacturing process is 100% renewable (Renewable mix) or the EU average mix (Residual mix)



Source: JRC.

SAP production was identified as a hotspot in almost all most relevant impact categories. Because SAP production data were based on literature, and modelled for this purpose, it was possible to further investigate the most relevant processes within the SAP production dataset. It was noticed that electricity consumption has the highest share of the impacts in many impact categories. Thus the assumption on electricity consumption was also explored in the sensitivity analysis. In the absence of knowledge of the range of electricity consumption levels for SAP production, it was decided to test an arbitrary choice of -20%. The analysis showed that such a decrease in electricity consumption would have a very limited impact on the total results for baby diapers. Only in the case of Ionising Radiation is the impact decrease significant, 11% (see **Figure 31**), but since Ionising Radiation is not among the most relevant impact categories for this model the main conclusions would not be affected by a change in electricity consumption.

Figure 31. Comparison of baby diaper results when the electricity used in the SAP manufacturing process is 20% lower than in the baseline assumption



Source: JRC.

4.4.3.13 Conclusions

The environmental hotspots identified in this study are mainly related to the production of raw materials, which has a contribution between 76% (Climate Change) and 102% (Resource Use - fossils) for baby diapers, and between 91% (Eutrophication, terrestrial) and 100% (Resource Use – fossils and Resource Use - minerals and metals) for sanitary towels. These findings are in line with other studies (Cordella et al., 2015; Mendoza et al., 2019; Hait and Powers, 2019; UNEP, 2021).

The raw materials showing the highest contributions in the case of baby diapers are SAP (which also has the highest share of materials used in diapers), fluff pulp, and PP, LDPE and PET granulates. For sanitary towels, the most contributing raw materials are viscose, fluff pulp, and PET, PP and LDPE granulates. In addition to LDPE used in sanitary towel production, the LDPE granulates used for sanitary towel packaging were also identified as a hotspot in some impact categories. Mazgai et al. (2021) also observed the importance of LDPE foil in the sanitary towel life cycle.

In addition to raw materials and packaging, transportation of raw materials and packaging are also identified to have a high contribution in some impact categories (Acidification and Eutrophication - terrestrial) mainly due to the train transportation, for which the EF transport scenarios were used (Zampori & Pant, 2019). In the case of baby diapers, emissions from the landfilling of diapers also have a high contribution in the Climate Change impact category, which also had high importance in the Hoffman et al. (2020) study.

Product manufacturing has only a very small share of the impacts, which is also in line with other studies. However, in this study, all companies reported using only renewable energy in the manufacturing. The impact of the use of only renewable energy was explored in the sensitivity analysis. According to the results of the sensitivity analysis, a change from renewable electricity to the European average mix would not cause significant differences in the results in the majority of the impact categories. The difference is significant only for Ionising Radiation, due to the presence of nuclear energy in the average electricity mix. However, since Ionising Radiation is not among the most relevant impact categories, the main conclusions would not be changed by using a different electricity mix.

SAP production was identified as a hotspot in almost all most relevant impact categories. Electricity consumption was identified as the most relevant process in SAP production in many impact categories. SAP production was modelled according to literature data in this study; thus, the assumption on electricity consumption was also explored in the sensitivity analysis. The analysis showed that a 20% decrease in electricity consumption would have a very limited impact on the total results for baby diapers. Only in the case of Ionising Radiation is the impact decrease significant (11%), but since Ionising Radiation is not among the most relevant impact categories for this model the main conclusions would not be affected by a change in electricity consumption.

The Data Quality Level is good (score 2.04) for baby diapers and very good (score 1.66) for sanitary towels. Although the score for both baby diapers and sanitary towels is good, it can be noticed that while the geographical and technological representativeness of the dataset is high (<3), the precision and time representativeness have lower scores. Only manufacturing of baby diapers and sanitary towels is based on primary data; all other data are secondary data from databases or literature. This is due to the nature of the study which uses data from the manufacturing companies although most of the relevant processes are beyond the control of these companies. To increase the quality of the study, more primary data should be used, especially for the processes identified as the most relevant ones, e.g. main raw materials production. In addition, it is not known how well the data received from companies represent the average baby diaper and sanitary towel production, because the market shares or sizes of these companies are not known. Also, it is not known if other companies, which did not provide data, use different raw materials with higher or lower impacts.

4.4.4 Screening LCA study: RMCs in Europe

4.4.4.1 Summary of the screening LCA study for RMCs

The goal of the study is to assess the environmental impacts of an average reusable menstrual cup, made either from medical-grade silicone or thermoplastic elastomer (TPE), using the Product Environmental Footprint (PEF) methodology. The results of the assessment will be used to develop a new set of EU Ecolabel criteria for RMCs. The results are not intended to define thresholds, but to find hotspots that the criteria should focus on. There are no PEFCRs for this kind of product, thus this study is performed as a screening study following general PEF methodology rules defined in Zampori & Pant (2019). The study is not intended to define PEF category rules.

The study was conducted by collecting data from RMC manufacturing companies. The system boundary includes all life-cycle stages from the raw material acquisition to the End-of-Life. Raw material acquisition includes production of raw materials used in the product manufacturing, production of packaging, and their transportation to the manufacturing site. Manufacturing of products includes energy and other inputs used in the manufacturing process and treatment of scraps from the manufacturing process. Distribution includes transport from the manufacturing site to the retail and final user. The use phase includes water and soap consumption for washing of hands and the cup, as well as water and energy for sterilisation of the cup before use and between cycles. The EoL phase includes the EoL of both the main product and the packaging. Retail was assumed to have only small impacts, thus retail was excluded from the assessment.

The environmental hotspots identified in this study are related to the use phase. More specifically, they relate to tap water and soap used to wash hands and the cup, as well as to a lesser extent wastewater treatment after washing hands and the cup, and electricity used for sterilisation of the cup before the first use and between cycles. However, these impacts are strongly related to assumptions regarding consumer behaviour and can vary significantly between consumers. The assumption on the replacement interval was looked at in the sensitivity analysis and it was noticed that increasing the interval from 8 hours (baseline scenario) to 12 hours (maximum time between replacements) would decrease the impacts by between 15% and 33%. A sensitivity analysis was also performed for lifetime of the cups, and TPE recycling, but both of them had only a very limited impact on the total results.

Due to the high impact of the use phase, the results were also calculated without it. In that case, the production of cotton packaging was identified as a hotspot in almost all relevant impact categories, and to a lesser extent also cardboard packaging in some impact categories. In addition, the main raw material production, especially silicone, was a hotspot in some impact categories, i.e. silicone had high relevance in the Resource Use – minerals and metals and Human Toxicity – non-cancer impact categories, which were not among the most relevant impact categories when the use phase was included. TPE was among the most important impact categories, but with lower importance, due to the lower amount of material needed for a TPE cup.

The Data Quality Level is very good (score 2.0) for both RMCs. Although the score is very good, it does not represent the data quality of the manufacturing of RMCs well, because the main contributing processes were related to the use phase. Only manufacturing of RMC is based on primary data; all other data are secondary data from databases or literature. To increase the quality of the study, more primary data should be used, especially for the main raw materials used in the manufacturing, i.e. silicone and thermoplastic elastomer. In addition, the representativeness of the manufacturing data are not known, i.e. the market shares of the companies that provided data, and the market shares of the different cup sizes.

The third-party verification concluded that the study is technically performed correctly. The LCA approach is consistent and compliant with the most recent version of the PEF methodology. Due to the nature of the study, not all PEF reporting requirements could be fully met, but this makes no difference to the results. The limitations and representativeness of the conclusions are sufficiently explained, and the study finds and discusses the environmental hotspots in a way that they can be used for the development of ecolabel criteria.

4.4.4.2 Goal of the study

The present study is part of an initiative for the revision and update of the EU Ecolabel criteria on absorbent hygiene products (AHPs), the scope of which was extended to also cover RMCs. The goal of the study is to assess the environmental impacts of an average reusable menstrual cup using the PEF methodology to find out the most relevant impact categories, life-cycle stages, processes and flows. The results of the assessment will be used to develop new EU Ecolabel criteria for RMCs. The results are not intended to define thresholds, but to find hotspots that the criteria should focus on. There are no PEFCRs for this type of product, thus this study is performed as a screening study following general PEF methodology rules defined in Zampori & Pant (2019). The study is not intended to define PEF category rules.

The study is targeted at all the stakeholders who are following or involved in the revision of the EU Ecolabel criteria for AHPs and development of new criteria for RMCs, namely AHP and RMC EU Ecolabel applicants and other manufacturers, suppliers of AHP and RMC materials, competent bodies, NGOs, the EU Ecolabel board and other EU Commission services.

4.4.4.3 Scope of the study

4.4.4.3.1 Functional unit and reference flow

The functional unit of the study is 10 years of use of the average product produced and marketed in the European Union. The average product is defined using the average composition and weight of the products of the companies providing the data, with a distinction according to two common raw materials used in the cups; medical-grade silicon and thermoplastic elastomer. Thus the functional units are as follows:

- 10 years of use of a reusable menstrual cup made from medical-grade silicone based on data from two manufacturing companies (three production sites).
- 10 years of use of a reusable menstrual cup made from thermoplastic elastomer (TPE) based on data from one manufacturing company.

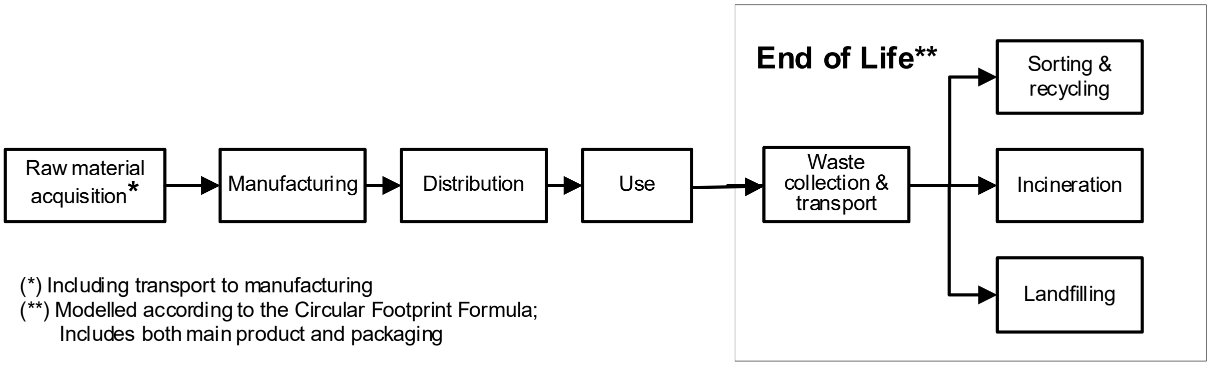
In the case of silicone cups, Company 1 has two manufacturing sites. The average production of Company 1 is based on the average production in these two sites assuming a 50% share for both sites, as the volumes of each manufacturing site were not known. After calculating the average of Company 1, the European average was determined assuming a 50% share of each company from which data were received (Company 1 and Company 2), because the market shares of the companies were not available. Thermoplastic elastomer is based only on one company's data.

According to companies, the silicone cup can be used for 10 years, thus the reference flow of reusable menstrual cups made from medical-grade silicone is one piece. In the case of TPE, the use varies between 3 and 5 years (MyCup, 2014). In the base case, 4 years of usage is assumed; thus, the reference flow of TPE cups is 2.5 pieces. The impact of the use time assumption is reviewed in the sensitivity analysis (Section 4.4.4.12.2).

4.4.4.3.2 System boundary

The system boundary includes all life-cycle stages from the raw material acquisition to the EoL (**Figure 32**). Raw material acquisition includes production of raw materials used in the product manufacturing, production of the packaging, and their transportation to the manufacturing site. The manufacturing stage includes energy and other inputs used in the cup manufacturing process, and treatment of scraps from the manufacturing process. Distribution includes transportation of the product from the manufacturing site to the retail and from retail to the end user. The use phase includes water and soap used in the washing of hands and the cup, water and electricity used in the sterilisation of the cup, as well as waste water treatment of the water used in washing and sterilisation. The EoL phase includes the EoL of both the main product and the packaging. Retail was assumed to have only small impacts in the cup life cycle, and is thus excluded from the assessment.

Figure 32. System boundary of reusable menstrual cups



Source: JRC.

4.4.4.4 Environmental Footprint impact categories

The EF 3.0 method, as implemented in the SimaPro 9.2 software, was used in the study, with the correction of the turbine water flows naming to correspond with the flow names in the EF 2.0 database processes. A list of impact categories with the respective impact category indicators, units and impact assessment models is presented in **Table 35**.

Table 35. Impact categories with respective impact category indicators, units and impact assessment models used in the assessment

Impact Category	**Impact Category indicator**	**Unit**	**Impact Assessment Model**
Climate Change, total (1)	Radiative forcing as Global Warming Potential (GWP_{100})	kg CO_2 eq	Baseline model of the IPCC over a 100-year time horizon (IPCC, 2013)
Ozone Depletion	Increase of stratospheric ozone breakdown as Ozone Depletion Potential (ODP)	kg CFC-11 eq	Steady-state model of the World Meteorological Organization over an infinite time horizon (WMO, 2014 + integrations)
Human Toxicity – cancer	Comparative Toxic Unit for humans (CTU_h)	CTU_h	USEtox model 2.1 (Fankte et al., 2017)
Human Toxicity – non-cancer	Comparative Toxic Unit for humans (CTU_h)	CTU_h	USEtox model 2.1 (Fankte et al., 2017)
Particulate Matter	Impact on human health	Disease incidence	PM method recommended by UNEP (UNEP, 2016)
Ionising Radiation – human health	Human exposure efficiency relative to U^{235}	kBq U^{235} eq	Human Health effect model (Dreicer et al., 1995)
Photochemical Ozone Formation - human health	Tropospheric ozone concentration increase	kg NMVOC eq	LOTOS-EUROS model (Van Zelm et al., 2008) as implemented in ReCiPe 2008

Impact Category	Impact Category indicator	Unit	Impact Assessment Model
Acidification	Accumulated Exceedance (AE) of the critical load	mol H^+ eq	Accumulated Exceedance model (Seppälä et al., 2006; Posch et al., 2008)
Eutrophication – terrestrial	Accumulated Exceedance (AE) of the critical load	mol N eq	Accumulated Exceedance model (Seppälä et al., 2006; Posch et al., 2008)
Eutrophication – freshwater	Fraction of nutrients (P) reaching freshwater end compartment	kg P eq	EUTREND model (Struijs et al., 2009) as implemented in ReCiPe
Eutrophication – marine	Fraction of nutrients (N) reaching marine end compartment	kg N eq	EUTREND model (Struijs et al., 2009) as implemented in ReCiPe
Ecotoxicity –freshwater	Comparative Toxic Unit for ecosystems (CTUe)	CTUe	USEtox model 2.1 (Fankte et al, 2017)
Land Use	• Soil quality index (2) • Biotic production • Erosion resistance • Mechanical filtration • Groundwater replenishment	• Dimension less (pt) • kg biotic production • kg soil • m^3 water • m^3 ground-water	Soil quality index based on LANCA (Beck et al., 2010 and Bos et al., 2016)
Water Use	User deprivation potential (deprivation-weighted water consumption)	m^3 world eq	Available WAter REmaining (AWARE) as recommended by UNEP, 2016
Resource use – minerals and metals	Abiotic resource depletion (ADP, based on ultimate reserves)	kg Sb eq	CML 2002 (Guinée et al., 2002) as updated in Van Oers et al. (2002)
Resource use –fossils	Abiotic resource depletion – fossil fuels (ADP-fossil)	MJ	CML 2002 (Guinée et al., 2002) and Van Oers et al. (2002)

(1) The indicator “Climate Change, total” consists of three sub-indicators: Climate Change – fossil; Climate Change – biogenic; and Climate Change – land use and land use change.

(2) This index is the result of the aggregation, performed by the JRC, of the 4 indicators provided by the LANCA model as indicators for land use.

Source: JRC.

4.4.4.5 Additional environmental information

Biodiversity impacts are mainly related to raw material acquisition. In the case of reusable menstrual cups, the raw materials are not known as typical high-biodiversity-impact materials, and thus biodiversity impacts are not assessed in this study.

4.4.4.5.1 Assumptions and limitations

The main assumptions in the modelling are related to distribution, the use phase and EoL. Distribution of the product and EoL are modelled according to the PEF method, using values and scenarios included in the method (Zampori & Pant, 2019). The use phase is modelled according to literature data, but it depends largely on consumer behaviour. It was also assumed that retail has only small impacts in the RMC life cycle, thus it was not included in the assessment.

The limitations of the study are related to data availability, more specifically as follows:

- Only the manufacturing process is based on primary data; all other data are secondary data from databases and literature.
- The EF database 2.0 was used due to the lack of EF 3.0 datasets and therefore secondary data are older. This affects the time representativeness of the secondary dataset.
- The average data of manufacturing of silicone RMCs are based only on two companies (three different production sites), without knowledge of / taking into account their market share. Also, the companies produce different sizes of RMCs, and the market shares of the different sizes were not available either, and thus could not be taken into account when defining the average product. Because of these issues, the conductor of the study cannot be sure how well the data used in the modelling represents the average product in Europe.
- Only one company provided data on thermoplastic elastomer RMC manufacturing, thus it cannot be considered to represent average TPE cups well.
- The lack of primary data on the main materials (silicone and TPE) increases the uncertainty on the results of the study, although the share of the impact of raw materials is very low in all impact categories.

4.4.4.6 Life-cycle inventory analysis

Included life-cycle stages are following:

- raw material acquisition (including packaging production, and transport of raw materials and packaging);
- manufacturing of the product, including disposal of waste produced at the manufacturing site, and transportation of cups from the manufacturing site to the packaging site when applicable (Company 1);
- distribution of the product from the manufacturing site to the retail and final user;
- use phase, including hand and cup washing (water and soap), cup sterilisation (water and energy), as well as waste water treatment of water used in washing and sterilisation; and
- EoL (including both the main product and packaging).

A detailed description of the modelling choices of each life-cycle stage is provided in the following sections. Storage and retail are assumed to have almost zero impact on the total life cycle, and these impacts are not included in the assessment. In addition, potential impacts from additional washing of clothes because of possible leakage are assumed to be small, and are excluded from the assessment. Capital goods are not otherwise included in the assessment, but in the case of use of EF and Ecoinvent datasets they are included.

Life-cycle inventory data received from the companies is confidential data and cannot be published in this report. LCI data are thus included in the Confidential Annex prepared for the verifiers of the study.

4.4.4.6.1 Modelling choices

Modelling choices for raw material acquisition, manufacturing, distribution and EoL are explained as it follows.

4.4.4.6.2 Raw material acquisition

For the modelling of the production of raw materials used in reusable menstrual cup manufacturing, secondary data were used from the EF database 2.0. Reusable menstrual cups are made either of medical-grade silicone or thermoplastic elastomer (TPE). In addition, pigment can be used to colour the cups, but it is not used in all cases. A list of raw materials used is presented in **Table 36**.

Table 36. List of raw materials used in the production of reusable menstrual cups

Raw material	EF Dataset
Silicone	Silicone, high-viscosity {EU-28+EFTA} | hydrolysis and methanolysis of dimethyldichloro silane | production mix, at plant | >30 000 centipoise | LCI result
TPE	Styrene-butadiene rubber (SBR) {EU-28+EFTA} | Emulsion polymerisation of styrene and butadiene | production mix, at plant | 23.5% styrene | LCI result
Pigment	Iron oxide, red pigment {GLO} | Technology mix | Production mix, at plant | LCI result

Source: JRC.

Company-specific transportation distances for raw materials were used when reported by the company, or estimated according to the average distance between the production site and the country of origin (silicone cups). In the case of TPE cups, this information was not available; thus, the following EF default scenario from supplier to factory was used:

- 130 km by truck;
- 240 km by train;
- 270 km by barge.

Reusable menstrual cup packaging includes a textile bag (made from cotton or microfibre), cardboard box and user manual made from paper. A list of packaging materials and datasets used are presented in **Table 37**. However, data from Company 3 included information only of the weight of the textile bag. The amount of cardboard and paper were added according to data from Company 2, because the actual product weights were similar in those two companies, so it was assumed that the amount of packaging materials would also be similar.

Table 37. List of packaging materials and datasets used for packaging modelling

Material	Dataset name
Cotton bag	Textile, woven cotton {GLO}| market for | APOS, U (without transport)*
Microfibre bag	Polypropylene (PP) fibres {EU-28+EFTA} | polypropylene production, spinning | production mix, at plant | 5% loss, 3.5 MJ electricity | LCI result
Cardboard box	Corrugated board, uncoated {EU-28+EFTA} | Kraft Pulping Process, pulp pressing and drying | production mix, at plant | flute thickness 0.8- 2.8 mm, R1=88% | LCI result
Paper (for manual)	Graphic paper {EU-28+3} | production mix | at plant | per kg graphic paper | LCI result

* The Ecoinvent 3.6 market dataset was used to have an average market mix of cotton textile, but transport was excluded, and the EF transport scenario was used instead as described later.

Source: JRC.

The cotton bag was assumed to come from outside Europe, thus the following EF transport scenario was used:

- 1000 km by truck;
- 18000 km by transoceanic container ship.

The microfibre bag, cardboard packaging and paper for the manual were assumed to be produced in Europe. The following EF transport scenario for packaging materials was used:

- 230 km by truck;
- 280 km by train;
- 360 km by barge.

4.4.4.6.3 Manufacturing

Manufacturing of reusable menstrual cups is based on an injection moulding process in the manufacturing company, and it consumes only electricity, in addition to raw materials, in amounts reported by the manufacturing companies. The national average residual electricity mix was used according to manufacturing country. However, Company 3 did not know the energy consumption per cup, thus the average electricity consumption per gram of raw material of the two other companies was used. According to MyCup (2014), less energy is needed to produce TPE products compared to silicone. The difference was not specified; thus, in this study it was assumed to be 20% less. This assumption has a very limited effect on the final results, because the manufacturing phase has close to zero effect on the total impacts. In the case of Company 1, manufacturing and packaging take place in different sites, thus the transportation of manufactured RMCs from the manufacturing site to the packaging site was included in the manufacturing stage, using truck transport[45].

Companies 1 and 3 did not report any other outputs beside the main product; however, it is acknowledged that during the production process some pieces are discarded on the manufacturing line, for example due to errors in the process. To account for this, the same percentage as reported by Vilabrille Paz et al. (2022) was used for all companies. This percentage is applied only to the product without packaging, since the hypothesis is that the pieces are discarded before packaging. This waste material is treated with a worst-case scenario, i.e. using the EU average share between landfill[46] and incineration[47], 55% and 45% respectively (Zampori & Pant, 2019), although it is not the likely practice in manufacturing companies. In addition, this amount was added to the raw materials needed for production including the same origin and transportation distances as reported in Section 4.4.6.2.

4.4.4.6.4 Distribution

Distribution from the manufacturing site to the final client is modelled considering the default transport scenario in the PEF method (Zampori & Pant, 2019). The products are first transported to retail stores and from there to the final client. The underlying hypothesis is that 100% of the products are marketed via retail stores, although some of them are probably marketed via online shops. The EF intracontinental supply chain scenario is used from factory to retail, i.e. 3500 km transport from the factory to the retail by truck (100% of products). From retail to the final client the transport distance is 5 km, according to the EF scenario, of which 5% is transported by van and 62% by car. The remaining 33% is considered to be without impacts, i.e. on foot, bike or other human-powered transport. The car travel is representative of the consumer travel to a retail shop (e.g. a supermarket); hence the 5 km are allocated to the product proportionally to items bought at one time, considering an average shop of 30 items, both food and non-food products (Castellani et al., 2017). A summary of datasets and transport distances per unit of product is presented in **Table 38**.

Table 38. Summary of the mode of transport, distance and dataset used to model the distribution of products

Mode of transport	Share of products transported	Distance	EF Dataset
Truck from factory to retail	100%	3500 km	Articulated lorry transport, Euro 4, Total weight >32 t (with fuel) {EU-28+3} | diesel driven, Euro 4, cargo | consumption mix, to consumer | more than 32 t gross weight / 24.7 t payload capacity | Unit process, single operation
Car from retail store to final client	62%	5 km	Passenger car, average {GLO} | technology mix, gasoline and diesel driven, Euro 3-5, passenger car | consumption mix, to consumer | engine size from

45 Articulated lorry transport, Euro 4, Total weight >32 t (with fuel) {EU-28+3} | diesel driven, Euro 4, cargo | consumption mix, to consumer | more than 32 t gross weight / 24,7t payload capacity | Unit process, single operation.

46 Landfill of plastic waste {EU-28+EFTA} | landfill including leachate treatment and with transport without collection and pre-treatment | production mix (region specific sites), at landfill site | The carbon and water content are respectively of 62%C and and 0% Water (in weight %) | LCI result.

47 Waste incineration of plastics (unspecified) {EU-28+EFTA} | waste-to-energy plant with dry flue gas treatment, including transport and pre-treatment | production mix, at consumer | unspecified plastic waste | LCI result.

Mode of transport	Share of products transported	Distance	EF Dataset
			1.4 l up to >2 l | LCI result
Van from retail store to final client	5%	5 km	Articulated lorry transport, Euro 3, Total weight <7.5 t (with fuel) {EU-28+3} | diesel driven, Euro 3, cargo | consumption mix, to consumer | up to 7.5 t gross weight / 3.3 t payload capacity | Unit process, single operation

Source: JRC.

4.4.4.6.5 Use phase

The use phase takes into account additional washing of hands before the cup is removed/changed, washing the cup after it is removed/changed, and sterilisation of the cup before the first use and between cycles in boiling water. Hand washing after removing/changing the cup is not included in the study, because it was assumed that it is the same for all menstrual products. **Table 39** presents the EF datasets and amounts used for water, soap and electricity consumption for washing and sterilisation, as well as wastewater treatment of used water. The amounts were calculated using following assumptions:

- menstruation 13 times per year;
- 5 days per cycle;
- cup is replaced every 8 hours[48];
- all water used for washing goes to wastewater treatment.

The same use phase scenario is applied for all menstrual cups, i.e. cups made from silicone and TPE, but in the case of sterilisation before use, which has slightly higher energy consumption compared to sterilisation between cycles (longer boiling time), the impact is divided by the life cycle of one cup, i.e. by 10 years in the case of silicone cups and by 4 years in the case of TPE cups.

Table 39. EF datasets and consumption amounts used in the modelling of the use phase

Activity	Amount per one action	EF Dataset
Hand washing, water consumption	0.64 l	Tap water {EU-28+3} | technology mix | at user | per kg water | LCI result
Cup washing, water consumption	1 l	
Cup sterilisation, water consumption	0.65 l	
Hand washing, soap consumption	2.3 g	Soap production {RER} | technology mix | production mix, at plant | 100% active substance | LCI result *
Cup washing, soap consumption	1.88 g	

[48] Recommendations for how long the cups can be used vary, with some manufacturers recommending up to 12 hours. Since most recommendations are for about 8 hours, this is the value used. Given the high relevance of the impacts of the use phase, the sensitivity analysis is carried out with different use times (Section 4.4.4.4.12.2).

Activity	Amount per one action	EF Dataset
Cup sterilisation, electricity consumption	0.596 MJ (first use) 0.555 MJ (between cycles)	Residual grid mix {EU-28+3} | AC, technology mix | consumption mix, to consumer | 1 - 60 kV | LCI result
Wastewater treatment	All water used in hand and cup washing, and sterilisation	Treatment of residential wastewater, large plant {EU-28+EFTA} | waste water treatment including sludge treatment | production mix, at plant | 1 m^3 of waste water treated | LCI result

*Only production of soap is included; packaging and transportation of soap are excluded.

Source: Vilabrille Paz et al., 2022 and JRC.

4.4.4.6.6 End-of-Life

The EoL of the products was modelled using the Circular Footprint Formula (CFF) and considering separate scenarios for the EoL of the product and its packaging. The parameters used in the CFF are as follows:

- R1 is the share of recycled content in the raw materials. This parameter has been considered to be 0 due to the lack of data on the supply chain of materials. The only exceptions are cardboard used for the packaging and paper included in the packaging, which according to the EF dataset used have a recycled content of 88% and 21%, respectively.
- R2 is the share of materials sent to recovery at the EoL of the product. For the disposal of the silicone cup, as well as the textile and microfibre bag, this is considered to be 0. For the cardboard packaging and paper included in the packaging, Annex C in the PEF method (Zampori & Pant, 2019) provides the average value of R2 in the European market. For the TPE cup, the generic plastic packaging R2 value is used, because of the lack of actual data, while TPE is fully recyclable as a material.
- R3 is the share of material sent to energy recovery. The European average value of R3 for municipal solid waste sent to incineration was used for the silicone cup, as well as for the textile and microfibre bag (45%, from Annex C in the PEF method (Zampori & Pant, 2019)). For the TPE cup, cardboard packaging and paper included in the packaging, the share was calculated as 45%*(1-R2).
- A is the allocation factor of environmental burdens between the supplier and user of recycled material. Lower values allocate more burden on the waste producer. The values suggested in Annex C of the PEF method (Zampori & Pant, 2019) were used.
- Qsout/Qp represents the different quality of the secondary material produced in the recycling process compared to the quality of the virgin material. The values suggested in Annex C of the PEF method (Zampori & Pant, 2019) were used.

The values reported in **Table 40** were retrieved from the latest version of Annex C of the PEF method (Zampori & Pant, 2019). The table also reports the dataset used for landfilling (E_D), incineration with energy recovery (E_R) and recycling at the EoL ($E_{recyclingEoL}$). However, in reality TPE cups might not end up in the recycling, or if they are recycled the Qsout/Qp ratio would not be as high as assumed in this study. Thus, the impacts of these assumptions are reviewed in the sensitivity analysis (Section 4.4.4.12.3). For the recycling of cardboard, a custom dataset was created using data on energy consumption in cardboard production from Ecoinvent 3.6 (Wernet et al., 2016). All incineration processes include collection and transportation to incineration, while landfilling datasets include only transport, but not collection. Thus, 50 km collection by small truck[49] were added for the waste going to landfilling, and 50 km collection and 50 km of transport distance for the recycled fraction of the waste.

[49] Articulated lorry transport, Euro 3, Total weight <7.5 t (with fuel) {EU-28+3} | diesel driven, Euro 3, cargo | consumption mix, to consumer | up to 7.5 t gross weight / 3.3 t payload capacity | Unit process, single operation.

Table 40. Summary of the Circular Footprint Formula parameters used in the end-of-life modelling

Material	A	R1	R2	R3	Qsout/ Qp	Dataset used
Main product, silicone	-	0%	0%	45%	-	**E_R:** Waste incineration of plastics (unspecified) {EU-28+EFTA} | waste-to-energy plant with dry flue gas treatment, including transport and pre-treatment | production mix, at consumer | unspecified plastic waste | LCI result
						E_D: Landfill of plastic waste {EU-28+EFTA} | landfill including leachate treatment and with transport without collection and pre-treatment | production mix (region specific sites), at landfill site | The carbon and water content are respectively of 62%C and 0% Water (in weight %) | LCI result
Main product, TPE	0.5	0%	29%	32%	0.9	**$E_{recyclingEoL}$:** 0.6 kWh/kg* of "Residual grid mix {EU-28+3} | AC, technology mix | consumption mix, to consumer | 1 - 60 kV | LCI result"
						E_R: Waste incineration of plastics (unspecified) {EU-28+EFTA} | waste-to-energy plant with dry flue gas treatment, including transport and pre-treatment | production mix, at consumer | unspecified plastic waste | LCI result
						E_D: Landfill of plastic waste {EU-28+EFTA} | landfill including leachate treatment and with transport without collection and pre-treatment | production mix (region specific sites), at landfill site | The carbon and water content are respectively of 62%C and 0% Water (in weight %) | LCI result
Textile bag	-	0%	0%	45%	-	**E_R:** Waste incineration of textile, animal- and plant-based {EU-28+EFTA} | waste-to-energy plant with dry flue gas treatment, including transport and pre-treatment | production mix, at consumer | textile waste | LCI result
						E_D: Landfill of textile {EU-28+EFTA} | landfill including leachate treatment and with transport without collection and pre-treatment | production mix (region specific sites), at landfill site | The carbon and water content are respectively of 40%C and 12% Water (in weight %) | LCI result
Microfibre bag	-	0%	0%	45%	-	**E_R:** Waste incineration of plastics (unspecified) {EU-28+EFTA} | waste-to-energy plant with dry flue gas treatment, including transport and pre-treatment | production mix, at consumer | unspecified plastic waste | LCI result
						E_D: Landfill of plastic waste {EU-28+EFTA} | landfill including leachate treatment and with transport without collection and pre-treatment | production mix (region specific sites), at landfill site | The carbon and water content are respectively of 62%C and 0% Water (in weight %) | LCI result

<table>
<tr><th>Material</th><th>A</th><th>R1</th><th>R2</th><th>R3</th><th>Qsout/ Qp</th><th>Dataset used</th></tr>
<tr><td rowspan="2">Paper</td><td rowspan="2">0.5</td><td rowspan="2">21%</td><td rowspan="2">62%</td><td rowspan="2">17%</td><td rowspan="2">0.85</td><td>E_R: Waste incineration of paper and board {EU-28+EFTA} | waste-to-energy plant with dry flue gas treatment including transport and pre-treatment | production mix at consumer | paper waste</td></tr>
<tr><td rowspan="2">E_D: Landfill of paper and paperboard waste {EU-28+EFTA}</td></tr>
<tr><td rowspan="2">Cardboard packaging</td><td rowspan="2">0.2</td><td rowspan="2">88%</td><td rowspan="2">75%</td><td rowspan="2">11%</td><td rowspan="2">0.85</td></tr>
<tr><td>$E_{recyclingEoL}$: custom dataset* including:
0.16 kWh/kg* of “Residual grid mix {EU-28+3} | AC, technology mix | consumption mix, to consumer | 1 - 60 kV | LCI result”
0.51 kJ/kg of* “Thermal energy from natural gas {EU-28+3} | technology mix regarding firing and flue gas cleaning | production mix, at heat plant | MJ, 100% efficiency | LCI result”</td></tr>
</table>

*Based on Ecoinvent 3.6 (Wernet et al., 2016).

Source: JRC.

4.4.4.7 Modelling multi-functional processes

There are no multifunctional processes. The only multifunctional processes are present in the background datasets and are analysed using the PEF method.

4.4.4.8 Data collection

Data on bills of materials and on inputs and outputs at the manufacturing stage was collected from companies manufacturing RMCs using a data collection form provided by the JRC. Manufacturing data were received from two companies producing RMCs from medical-grade silicone, and one company using thermoplastic elastomer. According to the data from individual companies, the arithmetic mean data of companies 1 and 2 (silicon-based production) was calculated, without taking into account the market shares of the companies. In the case of TPE cups, only one company provided data, thus these data were used as they were. However, the use phase does not depend on the material or size of the RMCs, thus the same data were used for all companies, based on Vilabrille Paz et al. (2022). Data collected from companies are classified as confidential and cannot be published.

4.4.4.9 Data quality requirements and rating

The Data Quality Rating (DQR) of the average RMC was assessed using the criteria described in the PEF methodology. The most relevant processes were included in the rating. The data quality assessment uses four criteria that are scored independently from 1 to 5, with 1 being the highest score. The criteria are precision (P), time representativeness (TiR), geographical representativeness (GeR) and technological representativeness (TeR). Then, the score of each dataset is weighted, according to its share of impact, to give the final Data Quality Rating. The Data Quality Rating is presented in **Table 40** (silicone RMC) and **Table 42** (TPE RMC).

The final result is a very good (score 2.0) for both products. However, the most relevant processes are related to the use phase, and do not represent the quality of the manufacturing data. In fact, the quality of the data on the main raw materials (silicone and TPE) is lower (2.75) due to the use of proxy EF datasets.

Table 41. Data Quality Rating of silicone RMC

Dataset	Weight	TeR	GeR	TiR	P	DQR
Silicone RMC						**2.0**
Soap production {RER} | technology mix | production mix, at plant | 100% active substance | LCI result	54.9%	2	1	2	3	2.0
Tap water {EU-28+3} | technology mix | at user | per kg water | LCI result	38.1%	2	1	2	3	2.0
Residual grid mix {EU-28+3} | AC, technology mix | consumption mix, to consumer | 1 - 60 kV | LCI result	4.7%	2	1	2	3	2.0
Textile, woven cotton {GLO}| market for | APOS, U	0.9%	2	2	2	3	2.25
Silicone, high viscosity {EU-28+EFTA} | hydrolysis and methanolysis of dimethyldichloro silane | production mix, at plant | >30 000 centipoise | LCI result	0.6%	4	2	2	3	2.75
Treatment of residential wastewater, large plant {EU-28+EFTA} | waste water treatment including sludge treatment | production mix, at plant | 1m^3 of waste water treated | LCI result	0.5%	2	1	2	3	2.0

Source: JRC.

Table 42. Data Quality Rating of thermoplastic elastomer RMC

Dataset	Weight	TeR	GeR	TiR	P	DQR
Thermoplastic elastomer RMC						**2.0**
Soap production {RER} | technology mix | production mix, at plant | 100% active substance | LCI result	54.2%	2	1	2	3	2.0
Tap water {EU-28+3} | technology mix | at user | per kg water | LCI result	37.6%	2	1	2	3	2.0
Residual grid mix {EU-28+3} | AC, technology mix | consumption mix, to consumer | 1 - 60 kV | LCI result	4.9%	2	1	2	3	2.0
Textile, woven cotton {GLO}| market for | APOS, U	1.6%	2	2	2	3	2.25
Treatment of residential wastewater, large plant {EU-28+EFTA} | waste water treatment including sludge treatment | production mix, at plant | 1m^3 of waste water treated | LCI result	0.5%	2	1	2	3	2.0
Styrene-butadiene rubber (SBR) {EU-28+EFTA} | Emulsion polymerisation of styrene and butadiene | production mix, at plant | 23.5% styrene | LCI result	0.3%	4	2	2	3	2.75
Corrugated board, uncoated {EU-28+EFTA} | Kraft Pulping Process, pulp pressing and drying | production mix, at plant | flute thickness 0.8 - 2.8 mm, R1=88% | LCI result	0.3%	2	2	2	3	2.25
Freight train, average (with fuel) {EU-28+3} | technology mix, electricity and diesel driven, cargo | consumption mix, to consumer | average train, gross tonne weight 1000 t / 726 t payload capacity | Unit process, single operation	0.3%	2	1	2	3	2.0

Source: JRC.

4.4.4.10 Impact assessment results

Tables 43 and **44** present characterised, normalised and weighted results of 10 years of use of reusable menstrual cups made of medical-grade silicon and thermoplastic elastomer, respectively. Characterised results are presented per life cycle stage, and Climate Change subcategories are reported separately.

Table 43. Characterised, normalised and weighted impacts of 10 years of usage of an average silicone RMC, which is produced and marketed in the European Union

Impact category	Characterised impact						Normalised impact	Weighted impact
	Raw material acquisition	Manu-facturing	Distribution	Use	End-of-Life	Total		
Climate Change [kg CO_2 eq.]	2.37E-01	2.78E-03	3.13E-02	1.83E+01	1.13E-02	1.86E+01	2.30E-03	4.84E-01
Climate Change (fossil) [kg CO_2 eq.]						1.59E+01	-	-
Climate Change (biogenic) [kg CO_2 eq.]						2.51E+00	-	-
Climate Change (land use and land use change) [kg CO_2 eq.]						1.51E-01	-	-
Ozone Depletion [kg CFC-11 eq.]	6.12E-09	1.73E-12	7.13E-14	6.78E-07	-1.41E-11	6.84E-07	1.28E-05	8.05E-04
Ionising Radiation [kBq U^{235} eq.]	1.78E-02	1.61E-03	6.92E-05	1.60E+00	-2.57E-03	1.61E+00	3.82E-04	1.92E-02
Photochemical Ozone Formation [kg NMVOC eq.]	1.56E-03	5.52E-06	1.18E-04	6.03E-02	-2.00E-05	6.19E-02	1.53E-03	7.29E-02
Particulate matter [Disease incidence]	1.90E-08	9.20E-11	1.94E-09	1.50E-06	-2.95E-10	1.53E-06	2.56E-03	2.30E-01
Human toxicity - non-cancer [CTUh]	5.80E-08	1.20E-11	1.74E-10	8.63E-07	-2.38E-11	9.21E-07	4.01E-03	7.38E-02
Human Toxicity - cancer [CTUh]	5.92E-10	1.67E-13	6.86E-12	3.23E-08	-1.30E-12	3.29E-08	1.95E-03	4.15E-02
Acidification [mol of H^+ eq.]	2.08E-03	1.30E-05	3.02E-04	1.15E-01	-2.48E-06	1.17E-01	2.11E-03	1.31E-01
Eutrophication - freshwater [kg P eq.]	4.48E-05	1.23E-08	1.02E-07	5.53E-03	3.03E-08	5.58E-03	3.47E-03	9.72E-02
Eutrophication - marine [kg N eq.]	2.22E-03	2.49E-06	6.05E-05	1.34E-01	-1.34E-06	1.36E-01	6.95E-03	2.06E-01
Eutrophication - terrestrial [mol N eq.]	7.95E-03	5.08E-05	1.38E-03	3.94E-01	9.88E-05	4.04E-01	2.29E-03	8.48E-02
Ecotoxicity - freshwater [CTUe]	6.15E+00	1.99E-02	3.71E-01	1.01E+03	-1.65E-01	1.02E+03	2.38E-02	4.58E-01
Land Use [Pt]	1.67E+01	5.12E-03	3.72E-02	7.18E+02	-1.67E+00	7.33E+02	8.95E-04	7.10E-02
Water Use [m^3 world eq.]	1.75E+00	8.18E-03	2.73E-03	9.71E+01	-6.80E-03	9.88E+01	8.62E-03	7.33E-01
Resource Use - fossils [MJ]	2.97E+00	4.23E-02	4.26E-01	1.70E+02	-2.37E-01	1.73E+02	2.66E-03	2.21E-01
Resource Use - mineral and metals [kg Sb eq.]	5.00E-06	5.65E-10	1.80E-09	6.84E-05	-1.37E-08	7.34E-05	1.15E-03	8.70E-02

Source: JRC.

Table 44. Characterised, normalised and weighted impacts of 10 years of usage of an average thermoplastic elastomer RMC, which is produced and marketed in the European Union.

Impact category	Characterised impact						Normalised impact	Weighted impact
	Raw material acquisition	Manu-facturing	Distribution	Use	End-of-Life	Total		
Climate Change [kg CO_2 eq.]	4.01E-01	7.35E-03	7.56E-02	1.84E+01	1.59E-02	1.89E+01	2.34E-03	4.93E-01
Climate Change (fossil) [kg CO_2 eq.]						1.63E+01	-	-
Climate Change (biogenic) [kg CO_2 eq.]						2.52E+00	-	-
Climate Change (land use and land use change) [kg CO_2 eq.]						1.58E-01	-	-
Ozone Depletion [kg CFC-11 eq.]	1.16E-08	5.72E-15	1.73E-13	6.78E-07	-1.87E-11	6.90E-07	1.29E-05	8.11E-04
Ionising Radiation [kBq U^{235} eq.]	2.01E-02	5.53E-04	1.66E-04	1.65E+00	-5.45E-03	1.66E+00	3.94E-04	1.97E-02
Photochemical Ozone Formation [kg NMVOC eq.]	3.46E-03	5.20E-06	2.80E-04	6.04E-02	-6.30E-05	6.41E-02	1.58E-03	7.55E-02
Particulate matter [Disease incidence]	3.43E-08	5.77E-11	4.54E-09	1.51E-06	-6.12E-10	1.55E-06	2.60E-03	2.33E-01
Human toxicity - non-cancer [CTUh]	9.09E-09	3.12E-11	4.27E-10	8.64E-07	-4.78E-10	8.73E-07	3.80E-03	6.99E-02
Human Toxicity - cancer [CTUh]	3.08E-09	2.69E-13	1.68E-11	3.23E-08	-3.33E-10	3.51E-08	2.08E-03	4.42E-02
Acidification [mol of H^+ eq.]	4.05E-03	7.41E-06	7.01E-04	1.15E-01	-1.97E-05	1.20E-01	2.16E-03	1.34E-01
Eutrophication - freshwater [kg P eq.]	8.49E-05	1.76E-08	2.55E-07	5.53E-03	1.08E-07	5.62E-03	3.50E-03	9.79E-02
Eutrophication - marine [kg N eq.]	4.40E-03	1.95E-06	1.42E-04	1.34E-01	-8.20E-06	1.38E-01	7.07E-03	2.09E-01
Eutrophication - terrestrial [mol N eq.]	1.69E-02	2.13E-05	3.21E-03	3.95E-01	1.67E-04	4.15E-01	2.35E-03	8.72E-02
Ecotoxicity - freshwater [CTUe]	1.14E+01	2.17E-02	8.99E-01	1.01E+03	-3.63E-01	1.02E+03	2.40E-02	4.61E-01
Land Use [Pt]	3.12E+01	4.74E-04	9.29E-02	7.18E+02	-3.42E+00	7.46E+02	9.10E-04	7.23E-02
Water Use [m^3 world eq.]	3.19E+00	7.09E-04	6.77E-03	9.71E+01	-1.59E-02	1.00E+02	8.74E-03	7.44E-01
Resource Use - fossils [MJ]	5.83E+00	6.77E-02	1.03E+00	1.72E+02	-8.14E-01	1.78E+02	2.74E-03	2.29E-01
Resource Use - mineral and metals [kg Sb eq.]	4.58E-07	1.25E-10	4.43E-09	6.84E-05	-2.07E-08	6.89E-05	1.08E-03	8.17E-02

4.4.4.11 Interpretation of results

The most relevant impact categories, life-cycle stages, processes and flows are presented in **Tables 45** (silicone cups) and **46** (TPE cups). In these tables, the contribution of each impact category was calculated based on the normalised and weighted impacts, whereas characterised results were used to identify the most relevant life-cycle stages, processes and elementary flows. The respective contribution (in %) for each of the life-cycle stages, processes and elementary flows refers to the individual contribution for a specific impact category. Negative values were kept as negative to be able to see benefits from EoL, although the PEF method suggests using absolute values.

The most important impact categories for both products are: Water Use (24%), Climate Change (16%), Ecotoxicity – freshwater (15%), Particulate Matter (8%), Resource Use – fossils (7%), Eutrophication – marine (7%) and Acidification (4%).

The use phase is the most relevant life-cycle phase for both products, having a share between 98% (Acidification) and 99% (Ecotoxicity – freshwater) in the case of silicone cups, and 96% (Acidification) and 99% (Ecotoxicity – freshwater) in the case of TPE cups. Raw material acquisition has a share of around 1-2% in the case of silicone cups, and a little bit higher, 1-3%, in the case of TPE cups. The impact of all other life-cycle stages are negligible, with manufacturing impacts being almost zero for all relevant impact categories.

In the case of Water Use, tap water used for the washing of hands and the RMC is the most relevant process for both products, with more than a 100% contribution (due to negative impacts for example from wastewater treatment when water is returned to the environment). In all other impact categories, soap production is the most relevant process, and often also the only relevant process. In the case of Climate Change, wastewater treatment after washing hands and the RMC was identified as the second most relevant process, and in the case of Resource Use – fossils, electricity used in the households to sterilise the cup before the first use and between cycles.

As the use phase was identified as the most relevant life-cycle stage with a 98-99% share of the impacts, the most relevant impact categories, phases, processes and flows are also presented without the use phase in **Tables 47** (silicone cup) and **48** (TPE cup). Water Use and Climate Change are still the two most important impact categories for both products, with shares of 24% and 14% (silicone cups), and 28% and 15% (TPE cups), respectively. When the use phase is excluded from the assessment, raw material acquisition is the most relevant life-cycle stage for all impact categories and both products, with the shares between 84% and 100% (silicone cups), and 80% and 100% (TPE cups).

In the case of silicone cups, production of the cotton bag is the most relevant process in Water Use (92%), Climate Change (36%), Eutrophication – marine (80%), Particulate Matter (33%) and Ecotoxicity – freshwater (80%) impact categories, and the second most relevant in the Resource Use – fossils (32%) impact category. Silicone production is the most relevant process in the Resource Use – minerals and metals (95%) and Human Toxicity – non-cancer (95%) impact categories, which were not identified among the most relevant life-cycle stages when analysing results with the use phase. In some impact categories (i.e. Climate Change, Resource Use – fossils and Particulate Matter), production of corrugated board used for packaging was also identified among the most relevant processes with a lower share (14%, 14% and 8%, respectively).

In the case of thermoplastic elastomer cups, production of the cotton bag is again identified as the most relevant process in many impact categories, namely Water Use (97%), Climate Change (38%), Eutrophication – marine (77%), Ecotoxicity – freshwater (80%) and Acidification (41%), and the second most relevant in Resource Use – fossils (32%), Particulate Matter (34%) and Photochemical Ozone Formation (21%). Thermoplastic elastomer production is the most relevant process in the Resource Use – fossils impact category (36%), and among the most relevant processes in the Climate Change impact category (16%). Also in the case of TPE cups, production of corrugated board packaging was identified among the most relevant processes in Climate Change (17%), Resource Use – fossils (16%), Particulate Matter (10%) and Photochemical Ozone Formation (11%). In addition, transport processes are also among the most relevant processes in some impact categories, mainly train and lorry transport, which is due to the use of EF transport scenarios, which also include train transport, while in the case of silicone cups only lorry transport was reported by the companies.

Table 45. The most relevant impact categories, life-cycle stages, processes and elementary flows of silicone RMC

Most relevant impact category	[%]	Most relevant life-cycle stage	[%]	Most relevant processes	[%]	Most relevant elementary flows	[%]
Water Use	**24.4%**	Use	98.2%	Tap water, EU average	144%	Water, river	137%
		Raw material acquisition	1.8%				
		Distribution	0.0%				
		Manufacturing	0.0%				
		End-of-Life	0.0%				
Climate Change	**16.1%**	Use	98.5%	Soap production	49%	Carbon dioxide, fossil	63%
		Raw material acquisition	1.3%				
		Distribution	0.2%	Wastewater treatment	32%	Methane, fossil	15%
		End-of-Life	0.1%				
		Manufacturing	0.0%				
Ecotoxicity - freshwater	**15.2%**	Use	99.4%	Soap production	89%	Sulphur to water	35%
		Raw material acquisition	0.6%			Carbofuran to soil	13%
						Pyrene to water	12%
		Distribution	0.0%			Aluminium to soil	9%

Most relevant impact category	[%]	Most relevant life-cycle stage	[%]	Most relevant processes	[%]	Most relevant elementary flows	[%]
		Manufacturing	0.0%			Chloride to water	9%
		End-of-Life	0.0%			Aluminium to air	4%
Particulate Matter	**7.6%**	Use	98.6%	Soap production	121%	Particulate, <2.5 µm	59%
		Raw material acquisition	1.2%				
		Distribution	0.1%			Ammonia	26%
		Manufacturing	0.0%				
		End-of-Life	0.0%				
Resource Use – fossils	**7.3%**	Use	98.1%	Soap production	61%	Energy from natural gas	37%
		Raw material acquisition	1.7%			Energy from coal	23%
		Distribution	0.2%	Electricity, residual mix	21%	Energy from coal	18%
		Manufacturing	0.0%			Energy from uranium	15%
		End-of-Life	-0.1%				

Most relevant impact category	[%]	Most relevant life-cycle stage	[%]	Most relevant processes	[%]	Most relevant elementary flows	[%]
Eutrophication – marine	**6.8%**	Use	98.3%	Soap production	83%	Nitrate to water	81%
		Raw material acquisition	1.6%				
		Distribution	0.0%				
		Manufacturing	0.0%				
		End-of-Life	0.0%				
Acidification	**4.4%**	Use	98.0%	Soap production	90%	Ammonia	50%
		Raw material acquisition	1.8%				
		Distribution	0.3%			Sulphur dioxide	29%
		Manufacturing	0.0%			Nitrogen dioxide	10%
		End-of-Life	0.0%				

Source: JRC.

Table 46. The most relevant impact categories, life-cycle stages, processes and elementary flows of thermoplastic elastomer RMC

Most relevant impact category	[%]	Most relevant life-cycle stage	[%]	Most relevant processes	[%]	Most relevant elementary flows	[%]
Water Use	**24.4%**	Use	98.4%	Tap water, EU average	142%	Water, river	135%
		Raw material acquisition	1.6%				
		Distribution	0.0%				
		Manufacturing	0.0%				
		End-of-Life	0.0%				
Climate Change	**16.2%**	Use	99.3%	Soap production	49%	Carbon dioxide, fossil	64%
		Raw material acquisition	0.6%				
		Distribution	0.1%	Wastewater treatment	32%	Methane, fossil	15%
		Manufacturing	0.0%				
		End-of-Life	0.0%				
Ecotoxicity – freshwater	**15.1%**	Use	98.1%	Soap production	89%	Sulphur to water	35%
		Raw material acquisition	1.4%			Carbofuran to soil	13%
						Pyrene to water	12%
		Distribution	0.4%			Aluminium to soil	9%

Most relevant impact category	[%]	Most relevant life-cycle stage	[%]	Most relevant processes	[%]	Most relevant elementary flows	[%]
		End-of-Life	0.1%			Chloride to water	9%
		Manufacturing	0.0%			Aluminium to air	4%
Particulate Matter	**7.6%**	Use	98.7%	Soap production	119%	Particulate, <2.5 µm	59%
		Raw material acquisition	1.1%				
		Distribution	0.2%			Ammonia	26%
		Manufacturing	0.0%				
		End-of-Life	0.0%				
Resource Use – fossils	**7.5%**	Use	97.8%	Soap production	59%	Energy from natural gas	36%
		Raw material acquisition	1.8%			Energy from coal	22%
		Distribution	0.5%	Electricity, residual mix	21%	Energy from coal	18%
		Manufacturing	0.0%			Energy from uranium	15%
		End-of-Life	-0.1%				

Most relevant impact category	[%]	Most relevant life-cycle stage	[%]	Most relevant processes	[%]	Most relevant elementary flows	[%]
Eutrophication – marine	**6.9%**	Use	98.2%	Soap production	82%	Nitrate to water	81%
		Raw material acquisition	1.7%				
		Distribution	0.1%				
		Manufacturing	0.0%				
		End-of-Life	0.0%				
Acidification	**4.4%**	Use	97.9%	Soap production	88%	Ammonia	49%
		Raw material acquisition	1.8%				
		Distribution	0.4%			Sulphur dioxide	29%
		Manufacturing	0.0%			Nitrogen dioxide	11%
		End-of-Life	0.0%				

Source: JRC.

Table 47. The most relevant impact categories, life-cycle stages, processes and elementary flows of silicone RMC without the use phase. *Source: JRC.*

Most relevant impact category	[%]	Most relevant life-cycle stage	[%]	Most relevant processes	[%]	Most relevant elementary flows	[%]
Water Use	**24.0%**	Raw material acquisition	99.8%	Cotton packaging	92.4%	Turbine water in China	228%
		Manufacturing	0.5%				
		Distribution	0.2%				
		End-of-Life	-0.4%				
Climate Change	**13.5%**	Raw material acquisition	83.9%	Cotton packaging	36%	Carbon dioxide, fossil	80%
		Distribution	11.1%	Silicone production	29%		
		End-of-Life	4.0%	Cardboard packaging	14%		
		Manufacturing	1.0%	Passenger car	7%		
Resource Use – minerals and metals	**10.9%**	Raw material acquisition	100.2%	Silicone production	95%	Silver	34%
		Distribution	0.0%			Lead	24%
		Manufacturing	0.0%			Copper	20%
		End-of-Life	-0.3%			Gold	11%

Most relevant impact category	[%]	Most relevant life-cycle stage	[%]	Most relevant processes	[%]	Most relevant elementary flows	[%]
Human Toxicity – non-cancer	**8.6%**	Raw material acquisition	99.7%	Silicone production	95%	Mercury to air	95%
		Distribution	0.3%				
		Manufacturing	0.0%				
		End-of-Life	0.0%				
Resource Use - fossils	**7.5%**	Raw material acquisition	92.8%	Silicone production	41%	Energy from natural gas	25%
						Energy from oil	22%
		Distribution	13.3%	Cotton packaging	32%	Coal, hard	12%
		Manufacturing	1.3%			Energy from coal	11%
		End-of-Life	-7.4%	Cardboard packaging	14%	Natural gas	7%
						Crude oil	7%
Eutrophication - marine	**6.4%**	Raw material acquisition	97.3%	Cotton packaging	80%	Nitrate to water	75%
		Distribution	2.6%				

Most relevant impact category	[%]	Most relevant life-cycle stage	[%]	Most relevant processes	[%]	Most relevant elementary flows	[%]
		Manufacturing	0.1%			Nitrogen dioxide to air	16%
		End-of-Life	-0.1%				
Particulate matter	**5.8%**	Raw material acquisition	91.6%	Cotton packaging	33%	Particulates, < 2.5 µm	53%
		Distribution	9.4%	Train transport	23%		
		Manufacturing	0.4%	Silicone production	21%	Ammonia	27%
		End-of-Life	-1.4%	Cardboard packaging	8%		
Ecotoxicity – freshwater	**5.3%**	Raw material acquisition	96.4%	Cotton packaging	80%	Trichlorfon to soil	22%
						Chloride to water	17%
		Distribution	5.8%			Aluminium to air	14%
		Manufacturing	0.3%			Chlorpyrifos to soil	14%
		End-of-Life	-2.6%			Azadirachtin to soil	9%
						Aluminium to soil	5%

Source: JRC.

Table 48. The most relevant impact categories, life-cycle stages, processes and elementary flows of thermoplastic elastomer RMC without the use phase

Most relevant impact category	[%]	Most relevant life-cycle stage	[%]	Most relevant processes	[%]	Most relevant elementary flows	[%]
Water Use	**27.6%**	Raw material acquisition	100.3%	Cotton packaging	97%	Turbine water in China	239%
		Distribution	0.2%				
		Manufacturing	0.0%				
		End-of-Life	-0.5%				
Climate Change	**15.2%**	Raw material acquisition	80.2%	Cotton packaging	38%	Carbon dioxide, fossil	79%
		Distribution	15.1%	Cardboard packaging	17%		
		End-of-Life	3.2%	TPE production	16%	Methane, biogenic	6%
		Manufacturing	1.5%	Passenger car	10%		
Resource Use – fossils	**9.2%**	Raw material acquisition	95.4%	TPE production	36%	Energy from oil	39%
						Energy from natural gas	21%
		Distribution	16.8%	Cotton packaging	32%	Hard coal	12%
		Manufacturing	1.1%			Natural gas	7%
		End-of-Life	-13.3%	Cardboard packaging	16%	Crude oil	7%

<table>
<thead>
<tr><th>Most relevant impact category</th><th>[%]</th><th>Most relevant life-cycle stage</th><th>[%]</th><th>Most relevant processes</th><th>[%]</th><th>Most relevant elementary flows</th><th>[%]</th></tr>
</thead>
<tbody>
<tr><td rowspan="4">Eutrophication - marine</td><td rowspan="4">8.0%</td><td>Raw material acquisition</td><td>99.7%</td><td rowspan="2">Cotton packaging</td><td rowspan="2">77%</td><td rowspan="2">Nitrate to water</td><td rowspan="2">72%</td></tr>
<tr><td>Distribution</td><td>0.3%</td></tr>
<tr><td>Manufacturing</td><td>0.0%</td><td rowspan="2">Train transportation</td><td rowspan="2">15%</td><td rowspan="2">Nitrogen dioxide to air</td><td rowspan="2">20%</td></tr>
<tr><td>End-of-Life</td><td>0.0%</td></tr>
<tr><td rowspan="4">Particulate Matter</td><td rowspan="4">6.7%</td><td>Raw material acquisition</td><td>89.6%</td><td>Train transportation</td><td>36%</td><td rowspan="2">Particulates, < 2.5 µm</td><td rowspan="2">52%</td></tr>
<tr><td>Distribution</td><td>11.9%</td><td rowspan="2">Cotton packaging</td><td rowspan="2">34%</td></tr>
<tr><td>Manufacturing</td><td>0.2%</td><td rowspan="2">Ammonia</td><td rowspan="2">28%</td></tr>
<tr><td>End-of-Life</td><td>-1.6%</td><td>Cardboard packaging</td><td>10%</td></tr>
<tr><td rowspan="4">Ecotoxicity - freshwater</td><td rowspan="4">6.3%</td><td rowspan="2">Raw material acquisition</td><td rowspan="2">95.4%</td><td rowspan="4">Cotton packaging</td><td rowspan="4">80%</td><td>Trichlorfon to soil</td><td>23%</td></tr>
<tr><td>Chloride to water</td><td>20%</td></tr>
<tr><td>Distribution</td><td>7.5%</td><td>Aluminium to air</td><td>15%</td></tr>
<tr><td>Manufacturing</td><td>0.2%</td><td>Chlorpyrifos to soil</td><td>14%</td></tr>
</tbody>
</table>

Most relevant impact category	[%]	Most relevant life-cycle stage	[%]	Most relevant processes	[%]	Most relevant elementary flows	[%]
		End-of-Life	-3.0%			Azadirachtin to soil	9%
Acidification	**6.2%**	Raw material acquisition	85.5%	Cotton packaging	41%	Nitrogen dioxide	36%
		Distribution	14.8%	Train transport	27%	Ammonia	33%
		Manufacturing	0.2%			Sulphur dioxide	18%
		End-of-Life	-0.4%	Lorry transportation	12%		
Photochemical Ozone Formation	**5.1%**	Raw material acquisition	94.0%	Train transportation	51%	Nitrogen dioxide	62%
		Distribution	7.6%	Cotton packaging	21%		
		Manufacturing	0.1%			Nitrogen oxide	15%
		End-of-Life	-1.7%	Cardboard packaging	11%	NMVOC	13%

Source: JRC.

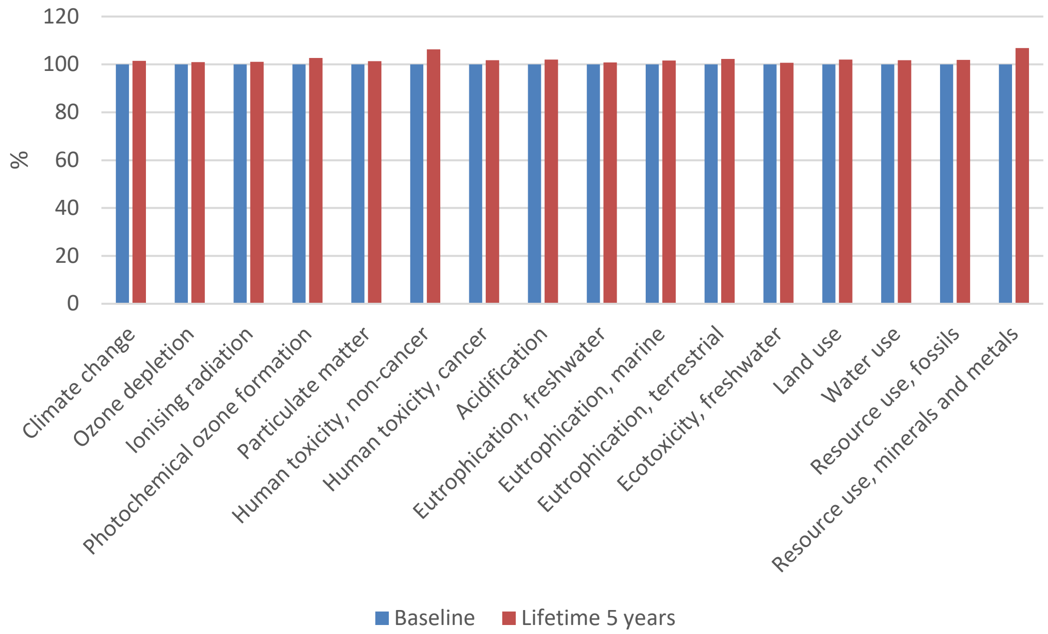
4.4.4.12 Sensitivity analysis

4.4.4.12.1 RMC lifetime

In the baseline scenario, the silicone RMC lifetime was assumed to be 10 years according to the information from the manufacturing companies. In some cases the lifetime can be shorter, and thus the impact of this assumption is reviewed in this sensitivity analysis. **Figure 33** compares the baseline impacts with the impacts if the lifetime of silicone RMCs were only 5 years, i.e. two cups would be needed during the 10-year period used in the study. According to Figure 2, the impact of the lifetime is very low. This is due to high impacts in the use phase. Only in the Resource Use – minerals and metals and Human Toxicity – non-cancer impact categories is the impact increase higher, between 6% and 7%. However, these impact categories are not identified among the most relevant impact categories, when the use phase is included.

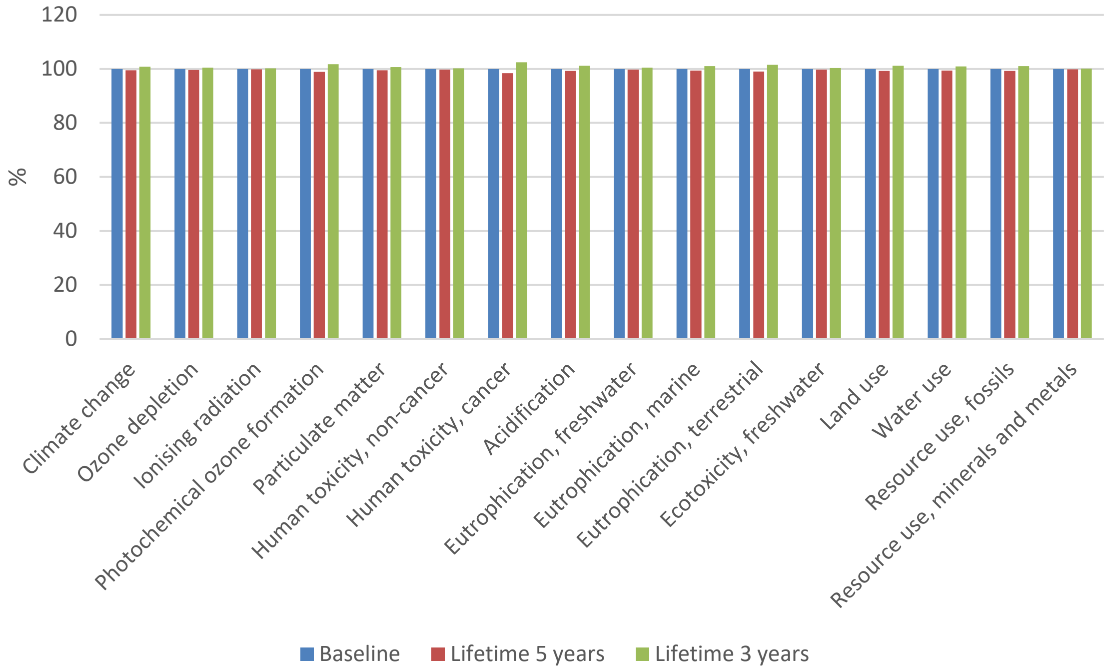
For TPE cups, the 4 year-lifetime was assumed in the baseline, i.e. the use of 2.5 cups during the 10-year period. **Figure 34** presents the comparison of the impacts, if the lifetime were 3 years (3.33 cups) or 5 years (2 cups). Also in case of the TPE cups, the lifetime assumption has only a marginal impact, less than 1% in most of the impact categories. Only in the case of Human Toxicity – cancer and Photochemical Ozone Formation is the change around 2% when the lifetime is increased or decreased.

Figure 33. Comparison of silicone RMC impacts, if the lifetime of the cup were 5 years instead of the 10 years assumed in the baseline



Source: JRC.

Figure 34. Comparison of thermoplastic elastomer RMC impacts, if the lifetime of cup were 5 or 3 years instead of the 10 years assumed in the baseline

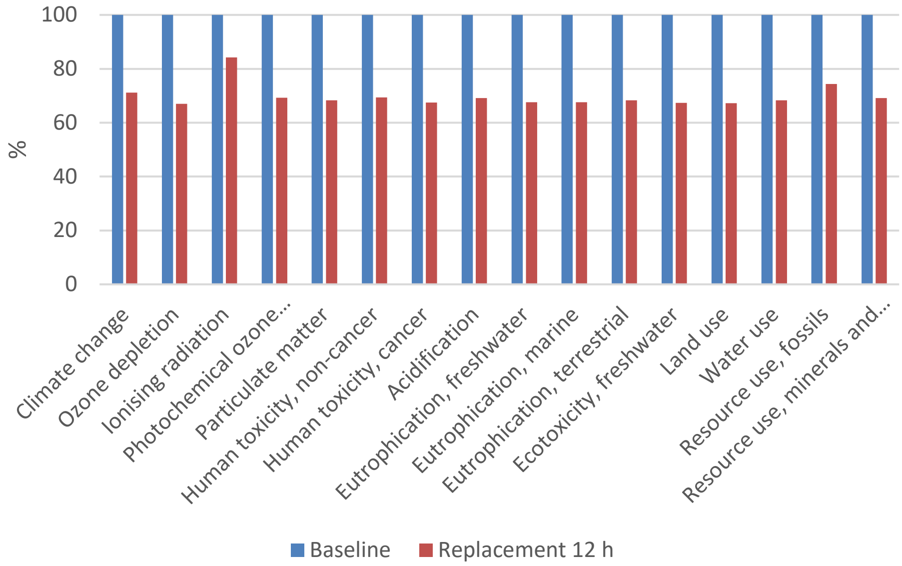


Source: JRC.

4.4.4.12.2 RMC replacement interval

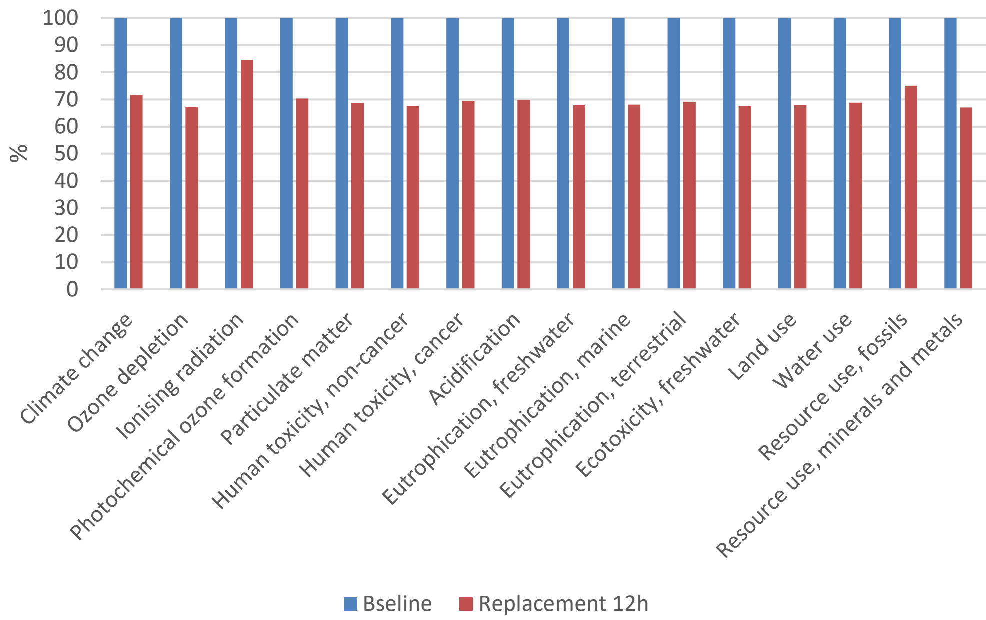
In the baseline scenario it was assumed that, due to hygienic and safety reasons, the cup will be changed/washed every 8 hours, i.e. three times per day. However, it should be possible to use cups up to 12 hours, i.e. change/wash it only twice a day. As the use phase was the dominating phase in all impact categories, this assumption is reviewed in this sensitivity analysis. Increasing the silicone RMC use time from 8 to 12 hours has a significant impact in all impact categories, between 33% (Ozone Depletion and Land Use) and 16% (Ionising Radiation) (**Figure 35**). In the case of TPE cups (**Figure 36**), the highest decrease can be noticed in Resource Use – minerals and metals, and Ozone Depletion (33%), and the lowest in Resource Use – fossils (15%).

Figure 35. Comparison of silicone RMC impacts, if the cup replacement interval were 12 hours instead of the 8 hours assumed in the baseline



Source: JRC.

Figure 36. Comparison of thermoplastic elastomer RMC impacts, if the cup replacement interval were 12 hours instead of the 8 hours assumed in the baseline

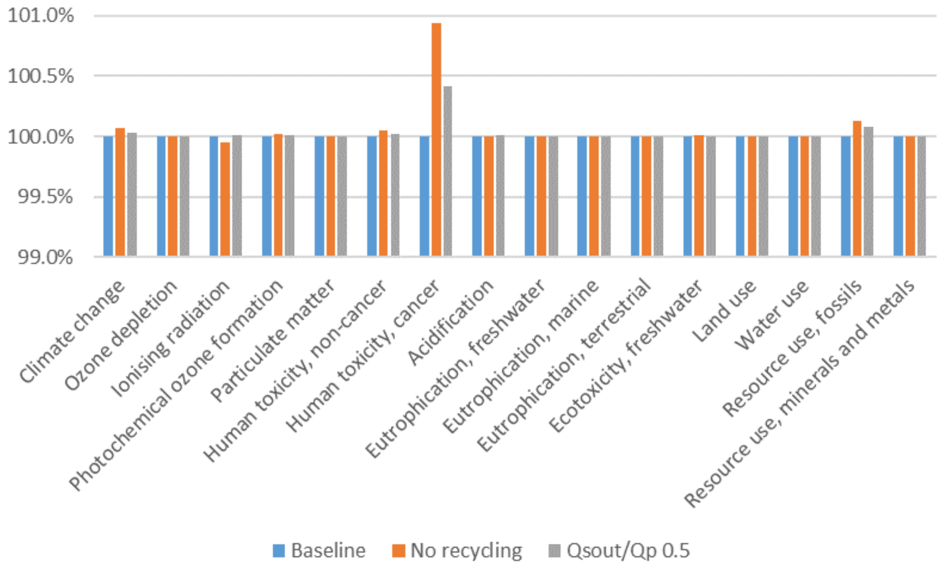


Source: JRC.

4.4.4.12.3 TPE recycling

In the base case, it was assumed that 29% of TPE cups are recycled with a Qsout/Qp ratio of 0.9. However, it is not very likely that TPE cups are recycled, or, if they are recycled, the quality ratio might be lower than the one used in this study. This sensitivity analysis compares the base line results in the situation in which 1) TPE cups are not recycled, or 2) the Qsout/Qp ratio is 0.5. Assumptions related to recycling have a very limited impact, less than 1% in all impact categories, and almost zero in most of the impact categories (**Figure 37**).

Figure 37. Comparison of TPE menstrual cup results (baseline) with the situation where 1) TPE cups are not recycled, and 2) the same amount as the baseline is recycled, but the Qsout/Qp ratio is 0.5 instead of 0.9



Note that y-axis values does not start from zero.

Source: JRC.

4.4.4.13 Conclusions

The environmental hotspots identified in this study are related to the use phase. More specifically, they related to tap water and soap used to wash hands and the cup, as well as to a lesser extent wastewater treatment after washing hands and the cup, and electricity used for sterilisation of the cup before the first use and between cycles. However, these impacts are strongly related to assumptions regarding consumer behaviour and can vary significantly between consumers. The assumption on the replacement interval was looked at in the sensitivity analysis and it was noticed that increasing the interval from 8 hours (baseline scenario) to 12 hours (maximum time between replacements) would decrease the impacts by between 15% and 33%. A sensitivity analysis was also performed for lifetime of the cups, and TPE recycling, but both of them had only a very limited impact on the total results.

Due to the high impact of the use phase, the results were also calculated without it. In that case, the production of cotton packaging was identified as a hotspot in almost all relevant impact categories, and to a lesser extent also cardboard packaging in some impact categories. In addition, the main raw material production, especially silicone, was a hotspot in some impact categories, i.e. silicone had high relevance in the Resource Use – minerals and metals and Human Toxicity – non-cancer impact categories, which were not among the most relevant impact categories when the use phase was included. TPE was among the most important impact categories, but with lower importance, due to the lower amount of material needed for a TPE cup.

The results of this study are similar to the Vilabrille Paz et al. (2022) study, which also identified the use phase as the most relevant life-cycle stage with more than a 95% share in almost all impact categories (UNEP, 2021). Other studies of reusable menstrual cups included only cup washing with cold water, without taking into account any additional hand washing, soap use or energy for sterilisation, thus the results are different. Hait and Powers (2019) identified transportation and the use phase as the most relevant life-cycle stages, while Leroy et al. (2016) identified packaging and the use phase as the most relevant.

The Data Quality Level is very good (score 2.0) for both RMCs. Although the score is very good, it does not represent the data quality of the manufacturing of RMCs well, because the main contributing processes were related to the use phase. Only manufacturing of RMC is based on primary data; all other data are secondary data from databases or literature. To increase the quality of the study, more primary data should be used, especially for the main raw materials used in the manufacturing, i.e. silicone and thermoplastic elastomer. In addition, the representativeness of the manufacturing data are not known, i.e. the market shares of the companies that provided data, and the market shares of the different cup sizes.

4.5 Assessment of EU Ecolabel criteria and improvement potential

Stakeholder's input is important to identify the main barriers that they encounter to comply with criteria. In the preliminary revision questionnaire, a set of questions was included in order to collect information regarding the stakeholders' opinion about each criterion, its verifiability and any other difficulties linked to compliance.

4.5.1 Feedback from the EU Ecolabel preliminary revision questionnaire

As explained in Section 2.6, in total 28 responses were received to the questionnaire. The majority of respondents were representative of EUEB members/Competent Bodies followed by industry supply companies who provide AHPs components and/or materials, as well as manufacturers of AHPs.

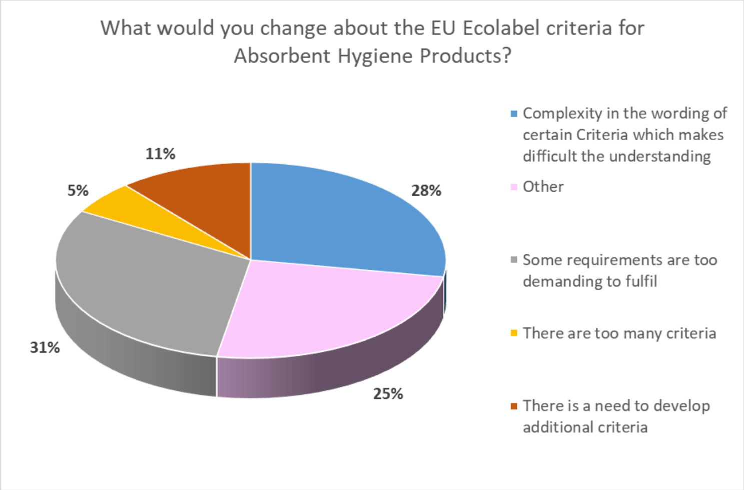
When asked on the main changes from the environmental point of view that have occurred in the past 5 years in the Absorbent Hygiene Product market sphere, stakeholders answered the following:

- The trend in the direction of sustainable wood/cellulose fibres and organic cotton.
- Higher market offer of environmentally friendly baby diapers manufactured with totally chlorine-free bleaching, without lotions, fragrances, EDCs (endocrine-disrupting chemicals) or other problematic chemicals. The offer of baby diapers which are FSC certified is also remarkably wide.
- There is a trend to promote reusable hygiene products.
- Consumers requesting 'greener', sustainable products (natural ingredients).
- Greater transparency when it comes to revealing the content of AHPs in terms of components, chemicals and other substances present in the products.
- No substantial increase of regulations or pressure from governments.
- The interest in public procurement has grown.
- CO_2 footprint discussions, customers asking for proof in the form of labels.
- TCF fluff introduction, drastic reduction of product weight, Ecolabel, Asthma Allergy (skin) and Ökotex-100 qualifications. Introduction of biobased materials and local Ecolabels.

The key market changes indicated by the majority of stakeholders derive from an increase in the environmental awareness of consumers and therefore the growing interest in purchasing "greener" products.

Stakeholders were also asked about the most relevant changes that should be considered during the upcoming revision (**Figure 38**).

Figure 38. General assessment of changes that should be targeted by the criteria revision



Source: JRC.

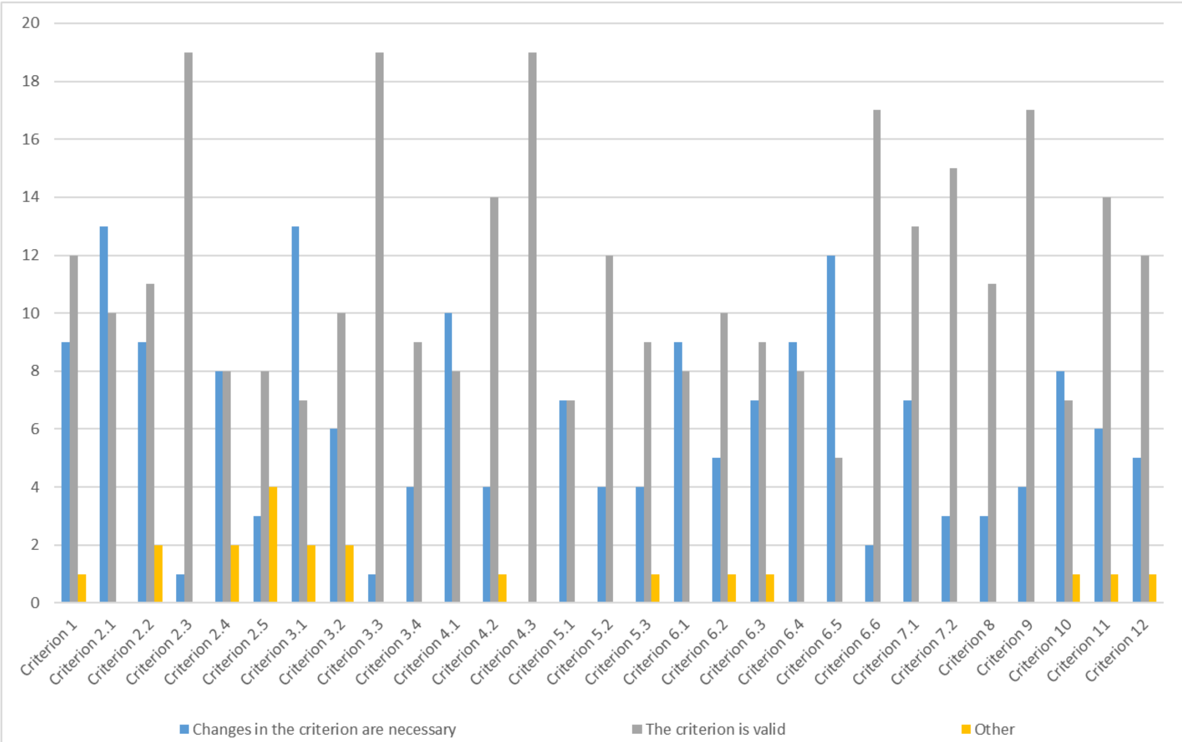
A significant number of the respondents indicated that some requirements are too demanding to fulfil while others mentioned the complexity in the wording in certain criteria (31% and 28%, respectively). One quarter of the stakeholders (25%) listed particular changes ("other") that should be considered during the revision; these could be summarised as follows:

- Expansion of the scope to incontinence products.
- Simplification of the supply chain control. The requirements should focus on the first or second tier.
- Criteria should better reflect the reality of product usage and consumer habits by product type (e.g. in % leakage criteria).
- Working with verifications can be resource- and time-consuming; thus, the revision of the EU Ecolabel for AHPs should strive to have a good balance between the documentation and verifications demanded by the criteria and the work required to collect them.
- The majority of stakeholders identified the requested laboratory testing as the key economical constraint of labelling a product. AHPs are assembled products with multiple supply streams and several levels of pre-supply chain. As a result, some of the respondents indicate the complexity to coordinate the needs along the value chain (suppliers, internal and external customers).
- There is a need to provide more clarity on non-skin-sensitising rosin esters and the presence of D4 and D5 in silicone.
- The EU Ecolabel should support the use of totally chlorine-free (TCF) bleaching and at the very least reduce further AOX emissions (adsorbable organic halides). EU ecolabelled AHP should be free from lotions, fragrances, EDCs and any other unnecessary chemicals. Requirements to ensure that none of the substances proposed for REACH restriction will be present in EU ecolabelled AHP.
- All pulp fibres shall be covered by valid chain of custody certificates issued by an independent third-party certification scheme such as FSC. However, the threshold should be raised to 70% pulp fibres (instead of the proposed 25%) to be covered by valid Sustainable Forestry Management certificates issued by an independent third-party certification scheme such as FSC.
- Support the use of biobased materials. Especially stimulate the use of other sustainable cotton sources besides organic cotton (Sub-criterion 4.1 and after the revision numbered as 3.1).
- The majority of stakeholders (46%) agree that the test methods and sampling frequency indicated in the preamble of Commission Decision (EU) 2014/763 are adequate and do not need to be changed.

While the Technical Report (published together with this Preliminary Report) will address in detail the stakeholders' opinions on each one of current EU Ecolabel criteria, a summary of the feedback collected is presented in **Figure 39**.

In general, respondents recognised the technical soundness of the currently valid criteria set. The criteria to which stakeholders commented the most (indicating the need for revision) are: Criterion 2.1 (Fluff Pulp - Sourcing), Criterion 3.1 (Man-made cellulose fibres - Sourcing), Criterion 4.1 (Cotton and other natural cellulosic seed fibres - Sourcing and traceability), Criterion 6.1 (Other materials and components-Adhesive materials), Criterion 6.4 (Other materials and components-Lotions), Criterion 6.5 (Other materials and components-Silicone) and Criterion 10 (Fitness for use and quality of the product), which need to be adapted. Split views were received with respect to the need for revision of Criterion 2.4 (Production of synthetic polymers and plastic materials Emission of COD and P to water and S compounds and NOx to air from production) and Criterion 5.1 (Production of synthetic polymers and plastic materials) and those who would not implement changes.

Figure 39. Summary of the stakeholders' opinion on the validity of the current EU Ecolabel criteria for AHPs



Source: JRC.

4.5.2 Improvement potential

The stakeholders' feedback as well as the conclusions of the screening LCA study will be used throughout the criteria revision process.

The revision of the criteria, in this initial stage of the revision process, has thus especially focused on the following (as detailed in the Technical Report 1):

- Production of raw materials: the criteria on the manufacture of fibres and on plastics were carefully revised and criteria improvements are proposed, when possible. The criterion on material efficiency in manufacturing is also proposed to be rediscussed with stakeholders.
- Packaging: a new criterion on packaging is proposed.
- The exploration of biobased plastic materials and compostable and/or biodegradable plastic materials is envisaged and proposed to be discussed during the revision process.

The transportation of the raw materials and packaging is outside the influence of the EU Ecolabel criteria. Similarly, environmental improvements in the EoL scenarios of AHPs are outside the remit of the EU Ecolabel criteria. Waste management scenarios applied across all EU Member States are not unified and only a couple of countries have industrial sites where baby diaper recycling is in place, thus making it difficult to achieve high rates of material recycling. Furthermore, as the composition of AHPs is a mixture of material types with organic material after use, recycling is difficult from a technical perspective but also economically expensive. Nevertheless, measures to incentivise the recycling of the packaging as well as reducing the generation of waste during manufacture have been proposed.

References

A Bon Entendeur, 2015. Available at: https://pages.rts.ch/emissions/abe/6759896-protections-hygieniques-le-test.html?anchor=6873505 (accessed 20/09/2021).

Aerts, O., Goossens, A., Lambert, J. and Lepoittevin, J.-P., 'Contact allergy caused by isothiazolinone derivatives: an overview of non-cosmetic and unusual cosmetic sources', *European Journal of Dermatology*, Vol. 27, No 2, Springer, 2017, pp. 115-22.

AHPMA, 2021. Feminine Hygiene. Available at: https://www.ahpma.co.uk/feminine-hygiene/ (accessed 26/08/2021).

Ajmeri, J.R. and Joshi Ajmeri, C., '4 - Nonwoven materials and technologies for medical applications', *Handbook of Medical Textiles*, Woodhead Publishing Series in Textiles, Woodhead Publishing, 2011, pp. 106-131.

Allied Market Research, 2020. Menstrual Cup Market by Product Type (Disposable and Reusable), Material (Medical Grade Silicone, Natural Rubber, and Thermoplastic Elastomer), and Distribution Channel (Online Stores and Pharmacies & Retail Stores): Global Opportunity Analysis and Industry Forecast, 2019–2026. Available at: https://www.alliedmarketresearch.com/menstrual-cup-market (accessed 30/08/2021).

Allied Market Research, 2021. Global Baby Diapers Market by Product Type, Size and Age: Opportunity Analysis and Industry Forecast, 2018 – 2025. Available at: https://www.alliedmarketresearch.com/baby-diapers-market (accessed 30/08/2021).

Allied Market Research, 2021. Tampon Market. Available at: https://www.alliedmarketresearch.com/tampon-market-A06099 (accessed 30/08/2021).

Andy Pandy: https://andypandykids.com/ (accessed 26/08/2021).

ANSES, 2015. *Exposition aux nanoparticules d'argent: mise à jour des connaissances.* Available at: https://www.anses.fr/fr/content/exposition-aux-nanoparticules-d%E2%80%99argent-mise-%C3%A0-jour-des-connaissances (accessed 29/08/2021).

ANSES, OPINION of the French Agency for Food, Environmental and Occupational Health & Safety on the safety of feminine hygiene products (2018). Available at: https://www.anses.fr/en/system/files/CONSO2016SA0108EN.pdf (accessed 29/08/2021).

AP News, 2021. Period Panties Market to Witness Increased Consumer Interest in Organic and Reusable Product Offerings: Future Market Insights Report. Available at: https://apnews.com/press-release/accesswire/technology-business-menstruation-health-united-arab-emirates-a64796f8cf36a584420c99af377427f1 (accessed 30/08/2021).

Arena, U., Ardolino, F. and Di Gregorio, F., 'Technological, environmental and social aspects of a recycling process of post-consumer absorbent hygiene products', *Journal of Cleaner Production,* Vol. 127, Elsevier, 2016, pp. 289-301.

Aumônier, S., Collins, M. and Garrett, P., *An updated lifecycle assessment study for disposable and reusable nappies*. Environmental Agency, England and Wales, 2008. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/291130/scho0808boir-e-e.pdf (accessed 29/08/2021).

Bachra., Y., Grouli, A., Damiri, F., Bennamara, A. and Berrada, M. 'A new approach for assessing the absorption of disposable baby diapers and superabsorbent polymers: A comparative study', *Results in Materials*, Vol. 8, Elsevier, 2020, pp. 100156.

Bae, J., Kwon, H. and Kim, J., 'Safety Evaluation of Absorbent Hygiene Pads: A Review on Assessment Framework and Test Methods', *Sustainability,* Vol. 10, No 11, MDPI, 2018, pp. 4146-4163.

Bajpai, P. *Biermann's Handbook of Pulp and Paper. Raw Material and Pulp Making*, Third Edition, Volume 1, Elsevier, 2018, https://doi.org/10.1016/C2017-0-00513-X.

Bambo Nature: https://www.bambonature.com/en/products/diapers (accessed 26/08/2021).

BBI JU, Biobased Industries Joint Undertaking: https://www.bbi.europa.eu/ (accessed 26/08/2021).

Beck, T., Bos, U., Wittstock, B., Baitz, M., Fischer, M., Sedlbauer, K. (2010). LANCA Land Use Indicator Value Calculation in Life Cycle Assessment – Method Report. Fraunhofer Institute for Building Physics.

Benavides, P. T., Lee, U. and Zare-Mehrjerdi, O., 'Life cycle greenhouse gas emissions and energy use of polylactic acid, bio-derived polyethylene, and fossil-derived polyethylene', *Journal of Cleaner Production,* Vol. 277, Elsevier, 2020, pp. 124010.

Benzinga, 2019. Sanitary Pad Market 2019: Global Key Players, Trends, Share, Industry Size, Sales, Supply, Demand, Analysis & Forecast to 2025. Available at: https://www.benzinga.com/pressreleases/19/11/ab14805157/sanitary-pad-market-2019-global-key-players-trends-share-industry-size-sales-supply-demand-analys (accessed 30/08/2021).

Bishop, G., Styles, D. and Lens, P. N. L., 'Environmental performance comparison of bioplastics and petrochemical plastics: A review of life cycle assessment (LCA) methodological decisions', *Resources, Conservation & Recycling*, Vol. 168, Elsevier, 2021, pp. 105451.

Blue Angel Ecolabel: https://www.blauer-engel.de/en (accessed 26/08/2021).

Blue Angel. The German Ecolabel. *Nappies, feminine hygiene and incontinence products (absorbent hygiene products, AHP)* DE-UZ 208 Version 3 (06/2021): Additions to 3.6.2 and 3.13. Available at: https://produktinfo.blauer-engel.de/uploads/criteriafile/en/DE-UZ%20208-202101-en%20Criteria-V3.pdf (accessed 27/08/2021).

Bolen, J., 'Thermoplastic Elastomer (TPE) vs Silicone Menstrual Cups', Reusable menstrual cup, 2020, https://reusablemenstrualcup.com/menstrual-cup-faqs/tpe-vs-silicone-menstrual-cups/ (accessed 26/08/2021).

Bos, U., Horn, R., Beck, T., Lindner, J.P., Fischer, M. (2016). LANCA® - Characterisation Factors for Life Cycle Impact Assessment, Version 2.0, 978-3-8396-0953-8Fraunhofer Verlag, Stuttgart.

Cabrera, A. and Garcia, R., *The Environmental & Economic Costs of Single-use Menstrual Products, Baby Nappies & Wet Wipes: Investigating the impact of these single-use items across Europe*. ZWE, 2019. Available at: https://zerowasteeurope.eu/wp-content/uploads/2019/12/bffp_single_use_menstrual_products_baby_nappies_and_wet_wipes.pdf (accessed 26/08/2021).

Carrefour, 2021. Baby diapers (several brands). Available at: https://www.carrefour.fr/s?q=couches (accessed 26/08/2021).

Castellani, V., Fusi, A., Sala, S. (2017). Consumer Footprint – Basket of Products indicator on Food. JRC Technical Reports. EUR 28764 EN. Publication Office of the European Union, Luxembourg.

Castrillon, N., Echeverria, M., Fu, H., Roy, A. and Toombs, J., 'Super absorbent polymer replacement for disposable baby diapers', Report number 1, University of California, Berkeley 2019, DOI:10.13140/RG.2.2.15095.98720.

Cavanagh, P., 2018. Global Fluff Pulp Outlook. RISI. Available at: https://events.risiinfo.com/latin-american-conference/sites/default/files/presentations/2018/Cavanagh%20Presentation.pdf (accessed 26/08/2021).

Cha, Y. U. and Park, M. J., 'Consumer preference and market segmentation strategy in the fast moving consumer goods industry: The case of women's disposable sanitary pads', *Sustainable Production and Consumption*, Vol. 19, Elsevier, 2019, pp. 130-140.

Chen, J., 'Chapter 4 - Synthetic Textile Fibers: Regenerated Cellulose Fibers', *Textiles and Fashion Materials, Design and Technology*, Woodhead Publishing Series in Textiles, 2015, pp. 79-95.

Chin, W., 'Thermoplastic Elastomer (TPE) Menstrual Cups', Chem On, 2020, https://www.chem-on.com.sg/article/TPE-Menstrual-Cup (accessed 26/08/2021).

China Environmental Labelling: http://en.mepcec.com/renzheng_column/113.html (accessed 26/08/2021).

China Environmental Labelling (2019). Technical requirement for environmental labelling products-Absorbent hygiene products: http://en.mepcec.com/upload/202004/20/202004200934578030.pdf (accessed 26/08/2021).

Commission Decision of 3 May 2000 replacing Decision 94/3/EC establishing a list of wastes pursuant to Article 1(a) of Council Directive 75/442/EEC on waste and Council Decision 94/904/EC establishing a list of hazardous waste pursuant to Article 1(4) of Council Directive 91/689/EEC on hazardous waste (notified under document number C(2000) 1147) (Text with EEA relevance) (2000/532/EC).

Commission Regulation (EU) No 10/2011 of 14 January 2011 on plastic materials and articles intended to come into contact with food.

Commission Decision of 24 October 2014 establishing the ecological criteria for the award of the EU Ecolabel for absorbent hygiene products (notified under document C (2014) 7735) OJ L 320, 6.11.2014, p. 46–63.

Commission Decision of 18 December 2014 amending Decision 2000/532/EC on the list of waste pursuant to Directive 2008/98/EC of the European Parliament and of the Council Text with EEA relevance.

Commission Implementing Decision (EU) 2019/1004 of 7 June 2019 laying down rules for the calculation, verification and reporting of data on waste in accordance with Directive 2008/98/EC of the European Parliament and of the Council and repealing Commission Implementing Decision C(2012) 2384 (notified under document C(2019) 4114).

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. New EU Forest Strategy for 2030. COM/2021/572 final.

Chemical Watch, India to develop standards for menstrual hygiene products, available at: https://chemicalwatch.com/175718/india-to-develop-standards-for-menstrual-hygiene-products (accessed 26/08/2021).

Claripharm cup: https://claripharm.com/menstrual-periods/menstrual-cups/ (accessed 29/08/2021).

Commission Implementing Regulation (EU) 2020/2151 of 17 December 2020 laying down rules on harmonised marking specifications on single-use plastic products listed in Part D of the Annex to Directive (EU) 2019/904 of the European Parliament and of the Council on the reduction of the impact of certain plastic products on the environment.

Cordella, M., Wolf, O., Schulz, M., Bauer, I., Lehmann, A., *Development of EU Ecolabel Criteria for Absorbent Hygiene Products (formerly referred to as "Sanitary Products"). Preliminary Report – Final.* European Commission, Joint Research Centre, 2013. Available at: https://susproc.jrc.ec.europa.eu/product-bureau//sites/default/files/contentype/product_group_documents/1581682328/Prelim%20Report%20AHP%20-%20final.pdf (accessed 26/08/2021).

Cordella, M., Wolf, O., Schulz, M., Bauer, I., Lehmann, A., 'Evolution of disposable baby diapers in Europe: life cycle assessment of environmental impacts and identification of key areas of improvement', *Journal of Cleaner Production,* Vol. 95, Elsevier, 2015, pp. 322-331.

Cotton Incorporated: https://www.cottoninc.com/ (accessed 26/08/2021).

Cotton Incorporated: 'Cotton Morphology and Chemistry', 2021. Available at: https://www.cottoninc.com/quality-products/nonwovens/cotton-fiber-tech-guide/cotton-morphology-and-chemistry/ (accessed 27/08/2021).

Cotton Incorporated: 'Monthly Economic Letter. Cotton Market Fundamentals & Price Outlook'. Available at: https://www.cottoninc.com/market-data/monthly-economic-newsletter/ (accessed 30/08/2021).

Council Directive 96/62/EC of 27 September 1996 on ambient air quality assessment and management.

Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91 (OJ L 189, 20.7.2007, p. 1).

Counts, J., Weisbrod, A. and Yin, S., 'Common Diaper Ingredient Questions: Modern Disposable Diaper Materials Are Safe and Extensively Tested', *Clinical Pediatrics*, Vol. 56, 5S, Sage, 2017, pp. 23S–27S.

Cradle to Cradle: https://www.c2ccertified.org/get-certified/product-certification (accessed 26/08/2021).

Cradle to Cradle Certified Products Registry: https://www.c2ccertified.org/products/registry (accessed 26/08/2021).

Danish Consumer Council THINK Chemicals, 2018. Test: Menstrual cups. Available at: https://kemi.taenk.dk/bliv-groennere/test-menstrual-cups (accessed 26/08/2021).

Das, D., '5 - Composite nonwovens in absorbent hygiene products', *Composite Non-Woven Materials, Structure, Properties and Applications,* Woodhead Publishing, 2014, pp. 74-88.

Desmedt, B., Marcelis, Q., Zhilivoda, D. and Deconinck, E., 'Sensitizing fragrances in absorbent hygiene products', *Contact Dermatitis*, Vol. 82, Wiley, 2020, pp. 279– 282.

Desrosiers, 2020. How Long Does a Menstrual Cup Last? Available at: https://www.menstrualcup.eco/blog/how-long-does-a-menstrual-cup-last (accessed 30/08/2021).

Dey, S., Kenneally, D., Odio, M., and Hatzopoulos, I., 'Review: Modern diaper performance: construction, materials, and safety review', *International Journal of Dermatology,* Vol. 55 (Suppl. 1), 2016, pp. 18–20.

Dey, S.; Purdon, M.; Kirsch, T.; Helbich, H.; Kerr, K.; Li, L.; Zhou, S., 'Exposure factor considerations for safety evaluation of modern disposable diapers', *Regul. Toxicol. Pharmacol.*, Vol.81, Elsevier, 2016, pp. 183-193.

Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

Directive (EU) 2018/852 of the European Parliament and of the Council of 30 May 2018 amending Directive 94/62/EC on packaging and packaging waste

Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment.

Dreicer, M., Tort, V., Manen, P. (1995). ExternE, Externalities of Energy, Vol. 5 Nuclear, Centre d'étude sur l'Evaluation de la Protection dans le domaine nucléaire (CEPN), edited by the European Commission DGXII, Science, Research and development JOULE, Luxembourg.

Dri M., Canfora P., Antonopoulos I. S., Gaudillat P., Best Environmental Management Practice for the Waste Management Sector, JRC Science for Policy Report, EUR 29136 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-80361-1, doi:10.2760/50247, JRC111059.

Easson, M., Edwards, J. V., Mao, N., Carr, C., Marshall, D., Qu, J., Graves, E., Reynolds, M., Villalpando, A., Condon, B., 'Structure/Function Analysis of Nonwoven Cotton Topsheet Fabrics: Multi-Fiber Blending Effects on Fluid Handling and Fabric Handle Mechanics', *Materials*, Vol. 11, No 11, MDPI, 2018, pp. 2077-2094.

EC (2020). Circular Economy Action Plan.

EC (2014). Summary of the meeting of the Regulatory Committee established under Article 16 of Regulation (EC) № 66/2010 of 25 November 2009 of the European Parliament and of the Council on the EU Ecolabel, 2014.

Eco Mark: https://www.ecomark.jp/english/ (accessed 26/08/2021).

Eco Mark (2017). Eco Mark Product Category No.104. "Household Textile Products Version3.4". Certification Criteria: https://www.ecomark.jp/english/pdf/104eC3.pdf (accessed 26/08/2021).

EDANA (2018). Supply Chain Information for Absorbent Hygiene Products: https://www.edana.org/docs/default-source/absorbent-hygiene-products/safety-and-regulatory-supply-chain-information-for-ahp-aug2018.pdf?sfvrsn=2555b491_2 (accessed 02/08/2021).

EDANA (2019). *New report forecasts excellent worldwide outlook for nonwovens through 2023*. Available at: https://www.edana.org/about-us/news/new-report-forecasts-excellent-worldwide-outlook-for-nonwovens-through-2023 (accessed 02/08/2021).

EDANA (2020). *Nonwovens markets, facts and figures*. Available at: https://www.edana.org/nw-related-industry/nonwovens-markets (accessed 02/08/2021).

EDANA (2020). *Stewardship Programme for Absorbent Hygiene Products. The Codex Document.* Available at: https://www.edana.org/docs/default-source/edana-product-stewardship-for-absorbent-hygiene-products/codex-final.pdf?sfvrsn=ebfc6249_4 (accessed 02/08/2021).

EDANA (2020). The relevant test methods. Available at: https://www.edana.org/how-we-take-action/edana-stewardship-programme-for-absorbent-hygiene-products/the-edana-absorbent-hygiene-product-stewardship-programme-codex/test-methods and https://www.edana.org/about-us/news/edana-ahp-stewardship-programme-to-give-consumers-further-assurances-about-the-safety-of-the-products (accessed 02/08/2021).

EDANA (2021*). European Nonwovens Production Exceeds 3 Million Tons*. Available at: https://www.nonwovens-industry.com/contents/view_breaking-news/2021-03-30/european-nonwovens-production-exceeds-3-million-tons/?widget=listSection and https://www.edana.org/about-us/news/2019-edana-nonwoven-statistics-released (accessed 02/08/2021).

EDANA (2021). Website https://www.edana.org/nw-related-industry/nonwovens-in-daily-life/absorbent-hygiene-products (accessed 02/08/2021).

Eijk, et al., 'Menstrual cup use, leakage, acceptability, safety, and availability: a systematic review and meta-analysis', *Lancet Public Health*, Vol. 4, The Lancet, 2019, pp. e376-e393.

EMBRACED project, 2021: https://www.embraced.eu/project (accessed 02/08/2021).

Espinosa-Valdemar R. M., Turpin-Marion S., Delfín-Alcalá I. and Vázquez-Morillas, A., 'Disposable diapers biodegradation by the fungus Pleurotus ostreatus', *Waste Management,* Vol. 31, No.8, Elsevier, 2011, pp. 1683–1688.

Espinosa-Valdemar R. M., Sotelo-Navarro, P. X., et al., 'Biological recycling of used baby diapers in a small-scale composting system', *Resources, Conservation and Recycling,* Vol. 87, Elsevier, 2014, pp. 153-157.

Eunomia (2020). Flexible films market in Europe. State of play. Production, collection and recycling data. Plastics Recyclers Europe. Available online at: https://743c8380-22c6-4457-9895-11872f2a708a.filesusr.com/ugd/dda42a_ff8049bc82bd408faee0d2ba4a148693.pdf

Euromonitor International: Tissue and Hygiene industry edition 2021. Data purchased.

European Commission (2021). EU Ecolabel Statistics: https://ec.europa.eu/environment/ecolabel/facts-and-figures.html (accessed 25/08/2021).

European Parliament (2019). Parliamentary questions: https://www.europarl.europa.eu/doceo/document/E-8-2019-001166-ASW_EN.html

Eurostat PROD COM List. 2019: https://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=PRD_2019&StrLanguageCode=EN&IntPcKey=45169040&StrLayoutCode=HIERARCHIC (accessed 02/08/2021).

Eurostat, 2021. Structural business statistics. Reference Metadata in Euro SDMX Metadata Structure (ESMS). Compiling agency: https://ec.europa.eu/eurostat/cache/metadata/en/sbs_esms.htm (accessed 02/08/2021).

Eurostat, 2021. Production of electricity and derived heat by type of fuel (nrg_bal_peh). Available at: https://ec.europa.eu/eurostat/databrowser/view/nrg_bal_peh/default/table (accessed July 2021).

Eurostat, 2021: Population on 1 January. Available at: https://ec.europa.eu/eurostat/databrowser/view/tps00001/default/map?lang=en (accessed July 2021).

Fact. MR, 2021. Baby Cloth Diaper Market. Available at: https://www.factmr.com/report/78/baby-cloth-diaper-market (accessed 30/08/2021).

Fantke, P., Bijster, M., Guignard, C., Hauschild, M., Huijbregts, M., Jolliet, O., Kounina, A., Magaud, V., Margni, M., McKone, T.E., Posthuma, L., Rosenbaum, R.K., van de Meet, D., van Zelm, R. (2017). Usetox®2.0 Documentation (Version 1).Available at: http://usetox.org.

Fava J. A., Curran M. A., Boustead I., Parrish R. 1990, 'Energy and environmental profile analysis of children's disposable and cloth diapers', *Peer Review Panel*, Comments on Franklin Associates, Ltd. Report. Kansas.

FDA report (not affiliated with the FDA), 2021. Menstrual cup manufacturers. Available at: https://fda.report/Product-Code/HHE (accessed 29/08/2021).

French Decree: Arrêté du 25 novembre 1992 relatif aux matériaux et objets en élastomères de silicone mis ou destinés à être mis au contact des denrées, produits et boissons alimentaires. Available at: https://www.legifrance.gouv.fr/loda/id/JORFTEXT000000178085/2020-12-22/ (accessed 20/09/2021).

FSC (Forest Stewardship Council). Available at: https://fsc.org/en (accessed 26/08/2021).

Future Market Insights, 2021. Period Panties Market. Available at: https://www.futuremarketinsights.com/reports/period-panties-market (accessed 30/08/2021).

Future Market Insights, 2021. Reusable Nursing Pads Market. Available at: https://www.futuremarketinsights.com/reports/reusable-nursing-pads-market (accessed 30/08/2021).

Gao, C.-J. and Kannan, K., 'Phthalates, bisphenols, parabens, and triclocarban in feminine hygiene products from the United States and their implications for human exposure', *Environment International*, Vol. 136, Elsevier, 2020, pp. 105465.

GECA (Good Environmental Choice Australia): https://geca.eco/ (accessed 26/08/2021).

GECA (2019). Sanitary Products: https://geca.eco/wp-content/uploads/2019/07/Sanitary-Products-Standard-SPv1.0-2019.pdf (accessed 26/08/2021).

Ghose A. and Chinga-Carrasco, G., 'Environmental aspects of Norwegian production of pulp fibres and printing paper', *Journal of Cleaner Production*, Vol. 57, Elsevier, 2013, pp. 293-301.

Gontia P. and Janssen M., 'Life cycle assessment of biobased sodium polyacrylate production from pulp mill side streams: case study of thermo-mechanical and sulfite pulp mills', *Journal of Cleaner Production*, Vol. 131, Elsevier, 2016, pp. 475-484.

GOTS (Global Organic Textile Standards): https://www.global-standard.org/the-standard (accessed 26/08/2021).

Grand View Research, 2018. Baby Diapers Market Size, Share & Trends Analysis Report Forecasts, 2012 – 2022. Report ID: 978-1-68038-664-6. Number of Pages: 115. Available at: https://www.grandviewresearch.com/industry-analysis/baby-diapers-market (accessed 26/08/2021).

Grand View Research, 2019. Super Absorbent Polymer (SAP) Market Size, Share & Trends Analysis Report By Application (Female Hygiene Products, Baby Diapers, Agriculture, Adult Incontinence Products), By Region, And Segment Forecasts, 2019 – 2025. Report ID: 978-1-68038-617-2. Number of Pages: 80. Available at: https://www.grandviewresearch.com/industry-analysis/super-absorbent-polymers-market (accessed 26/08/2021).

Guinée, J.B. (Ed.), Gorrée, M., Heijungs, R., Huppes, G., Kleijn, R., de Koning, A., Van Oers, L., Wegener Sleeswijk, A., Suh, S.,. Udo de Haes, H.A, De Bruijn, J.A., Van Duin R., Huijbregts, M.A.J. (2002). Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards. Series: Eco-efficiency in industry and science. Kluwer Academic Publishers. Dordrecht (Hardbound, ISBN 1-4020-0228-9; Paperback, ISBN 1-4020-0557-1).

Hait, A. and Powers, S. E., 'The value of reusable feminine hygiene products evaluated by comparative environmental life cycle assessment', *Resources Conservation and Recycling*, Vol. 150, Elsevier, 2019, pp. 104422.

Hakala S., Virtanen Y., Meinander K., Tanner T., 'Life-cycle assessment, comparison of biopolymer and traditional diaper systems', Technical Research Centre of Finland (VTT), 1997, *Research Notes* pp. 1876.

Hippybottomus: https://hippybottomus.com.au/collections/stay-dry-bamboo-cloth-nappies (accessed 26/08/2021).

Heo, J. J., Kim, U.-J. and Oh, J.-E., 'Simultaneous quantitative analysis of four isothiazolinones and 3-iodo-2-propynyl butyl carbamate in hygienic consumer products', *Environmental Engineering Research*, Vol. 24, No 1, KSEE, 2019, pp. 137-143.

Hoffmann, B. S., Morais, J. de S. and Fonseca Teodoro, P., 'Life cycle assessment of innovative circular business models for modern cloth diapers', *Journal of Cleaner Production*, Vol. 249, No 10, Elsevier, 2020, pp. 119364.

IFOP, 2021. LES FEMMES, LEURS RÈGLES ET LEUR ATTRAIT POUR LES CULOTTES MENSTRUELLES. Available at: https://www.ifop.com/publication/les-femmes-leurs-regles-et-leur-attrait-pour-les-culottes-menstruelles/ (accessed 26/08/2021).

Imarc Group, 2017. Global Feminine Hygiene Products Market to Reach USUSD 37.2 Billion by 2025, Catalyzed by Shift Toward Eco-Friendly Variants. Available at: https://www.imarcgroup.com/global-feminine-hygiene-products-market (accessed 30/08/2021).

Imarc Group, 2020. Global Feminine Hygiene Products Market Size, Industry Trends and Forecast Till 2025. Available at: https://www.medgadget.com/2020/08/global-feminine-hygiene-products-market-size-industry-trends-and-forecast-till-2025.html (accessed 30/08/2021).

Imarc Group, 2021. Sanitary Napkin Market. Available at: https://www.imarcgroup.com/sanitary-napkin-market (accessed 30/08/2021).

IPCC (2013). IPCC Climate Change Fifth Assessment Report: Climate Change 2013. Available online at: http://www.ipcc.ch/ipccreports/assessments-reports.htm (accessed July 2021).

Ishii, S., Fukushima, A., Katagiri, R., Sakunaga, M., Kuribara, I., Uchida, and T., Wada, M., 'Safety evaluation of recycling process used to produce recycled pulp for adult paper diapers', *Regulatory Toxicology and Pharmacology,* Vol. 122, Elsevier, 2021, pp. 104909.

Iacopetta, D., Catalano, A., Ceramella, J., Saturnino, C., Salvagno, L., Ielo, I., Drommi, D., Scali, E., Plutino, M.R., Rosace, G. and Sinicropi, M.S., 'The Different Facets of Triclocarban: A Review', *Molecules*, Vol. 26, MDPI, 2021, pp. 2811.

ISO 10993:2009 Biological evaluation of medical devices Standard.

ISO 10993-5:2009 Biological evaluation of medical devices — Part 5: Tests for in vitro cytotoxicity.

ISO 10993-10:2010 Biological evaluation of medical devices — Part 10: Tests for irritation and skin sensitization.

ISO 13485:2016 Medical devices. Quality management systems.

ISO 14021:2016 Environmental labels and declarations — Self-declared environmental claims (Type II environmental labelling).

ISO 14040:2006 Environmental management — Life cycle assessment — Principles and framework.

Itsubo, Wada, M., Imai, S., Myoga, A., Makino, N. and Shobatake, K., 'Life Cycle Assessment of the Closed-Loop Recycling of Used Disposable Diapers', *Resources*, Vol. 9, (3), MDPI, 2020, pp. 34.

Kakonke, G., Tesfaye, T., Sithole, B. and Ntunka, M., 'Review on the Manufacturing and Properties of Nonwoven Superabsorbent Core Fabrics used in Disposable Diapers', *International Journal of Chemical Sciences*, Vol. 17, Issue 1, Trade Science Inc., 2019, pp. 302-323.

Karimi, H., Yu, Q. L. and Brouwers, H. J. H., 'Valorization of waste baby diapers in concrete', *Resources, Conservation and Recycling*, Vol. 153, Elsevier, 2020, pp. 104548.

KEMI, 2018. *No reason for concern about chemicals in menstrual products.* Available at: https://news.cision.com/kemikalieinspektionen/r/new-report--no-reason-for-concern-about-chemicals-in-menstrual-products,c2557148 (accessed 29/08/2021).

Khilnani, 2018. Menstrual Cups Vs. Period Underwear. Available at: https://blogdroplethealth.wordpress.com/2018/07/24/menstrual-cups-vs-period-underwear/ (accessed 30/08/2021).

Khoo, S. C., Phang, X. Y., Ng, C. M., Lim, K. L., Lam, S. S. and Ma, N. L., 'Recent technologies for treatment and recycling of used disposable baby diapers', *Process Safety and Environmental Protection*, Vol. 123, Elsevier, 2019, pp. 116-129.

Kid Savers Network: https://kidsaversnetwork.com/newborn/the-pros-cons-of-bamboo-diapers/ (accessed 26/08/2021).

Klinter, L., Doctoral Dissertation: *Normalizing the Natural: A study of menstrual product destigmatization*. MediaTryck Lund, Lund University, 2021. Available at: https://portal.research.lu.se/portal/en/publications/normalizing-the-natural(930adfaf-ead2-469a-8821-1ad19ac2827a).html (accessed 26/08/2021).

Korea Eco-Label: http://el.keiti.re.kr/enservice/enindex.do (accessed 26/08/2021).

Kowalska, M. A., Donatello, S., Kaps, R., Wolf, O., Gama-Caldas, M., *Revision of the EU Ecolabel criteria for: Copying and Graphic Paper, Newsprint Paper and Tissue Paper, Draft Preliminary Report,* 2016. Available at: https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/contentype/product_group_documents/1581684000/Paper%20Products_Draft%20Preliminary%20report.pdf (accessed 26/08/2021).

Lalitha, P., Jayanthi, P. and Sujitha, R., 'Antimicrobial Activity of Perspiration Pads and Cotton Cloth Fabricated with the Ethyl Acetate Extract of Eichhornia crassipes (Mart.) Solms', *Journal of Textiles*, Hindawi, 2014, Article ID 943287.

Lebensmittel-, Bedarfsgegenstände-und Futtermittelgesetzbuch, or "Foods, Consumer Goods and Feedstuffs Code". Available at: http://www.gesetze-im-internet.de/lfgb/ (accessed 26/08/2021).

Lentz R., Franke M., Thomé-Kozmiensky K.J. 1989. Vergleichende Umweltbilanzen für Produkte am Beispiel von Höschen- und Baumwollwindeln. In: Thomé-Kozmiensky KJ (ed) Schenkel W. Konzepte in der Abfallwirtschaft; EF Verlag für Energie- und Umwelttechnik GmbH, Germany.

Leroy, Y., Yannou, B., Murthy, L., Lallmahomed, A. and Yannou-Le Bris, G., 'Which hygienic products for which continent? Design for usage and sustainability', *Proceedings of International Design Conference*, DS 84, DESIGN, 2016, pp. 311–320.

La casa del bambú, 2021. Braguitas menstruales: ¿cuánto tiempo puedes usarlas? Available at: https://lacasadelbambu.com/blogs/news/braguitas-menstruales-cuanto-tiempo-puedes-usarlas (accessed 30/08/2021).

Little Lamb: https://littlelambnappies.com/ (accessed 26/08/2021).

Loulou cup: https://en.louloucup.com/ (accessed 29/08/2021).

Luchese, C. L., Engel, J. B. and Tessaro, C., '14 - Disposable, reusable and biodegradable hygiene products', *Antimicrobial Textiles from Natural Resources*, The Textile Institute Book Series, Woodhead Publishing, 2021, pp. 421-454.

Luna Cup: https://lunacup.eu/en-GB/menstrual-cup/blog/post/what-are-lunacup-menstrual-cups-made-of (accessed 29/08/2021).

MADE SAFE: https://www.madesafe.org/ (accessed 26/08/2021).

Mahajan, T., 'Imperfect Information in Menstrual Health and the Role of Informed Choice', *Indian Journal of Gender Studies*, Vol. 26, No 1&2, Sage Journals, 2019, pp. 59–78.

Manfredi et al., Product Environmental Footprint (PEF) Guide, 2021, Joint Research Centre, European Commission. Available at: https://ec.europa.eu/environment/eussd/pdf/footprint/PEF%20methodology%20final%20draft.pdf

Mazgaj, M., Yaramenka, K. and Malovana, O., 'Comparative Life Cycle Assessment of Sanitary Pads and Tampons', 2006, GROUP 6, Royal Institute of Technology Stockholm.

Mendoza, J. M. F., Popa, S. A., D'Aponte, F., Gualtieri, D., Azapagic, A., 'Improving resource efficiency and environmental impacts through novel design and manufacturing of disposable baby diapers', *Journal of Cleaner Production*, Vol. 210, Elsevier, 2019, pp. 916-928.

Mendoza, J. M. F., D'Aponte, F., Gualtieri, D., Azapagic, A., 'Disposable baby diapers: Life cycle costs, eco-efficiency and circular economy', *Journal of Cleaner Production*, Vol. 211, Elsevier, 2019, pp. 455-467.

Menstrual Cups reviews, 'The Top 5 Organic Pads & Panty Liners – Reviewed', 2021. Available at: https://menstrualcupreviews.net/best-organic-cotton-pads-and-panty-liners/ (accessed 27/08/2021).

Menstrual Cups reviews, 'The Best 10 Organic Cotton Tampons Brands & Reviews', 2021. Available at: https://menstrualcupreviews.net/best-organic-cotton-tampons-brands-reviews/ (accessed 27/08/2021).

Mirabella, N.; Castellani, V and Sala, S., 'Life cycle assessment of biobased products: a disposable diaper case study', *International Journal of Life Cycle Assessment*, Vol. 18, Springer, 2013, pp. 1036–1047.

Mulherkar, J., 'Top 10 Brands That Make Eco-friendly Sanitary Pads', ThinkRightme, 2020, https://www.thinkrightme.com/en/do-right/our-planet/top-10-brands-that-make-eco-friendly-sanitary-pads/ (accessed 02/08/2021).

Mor, D., Bansal, S., Ramachandran, M. and Raichurkar, P., 'Review on Antibacterial, Antiviral, and Antifungal Properties of Natural Diapers and its Effect on Dermatitis', *International Journal of PharmTech Research*, Vol. 8, No.10, PharmTech, 2015, pp 40-46.

Musaazi, M. K., Mechtenberg, A. R., Nakibuule, J., Sensenig, R., Miyingo, E., Makanda, J. V., Hakimian, A., Eckelman, M. J., 'Quantification of social equity in life cycle assessment for increased sustainable production of sanitary products in Uganda', *Journal of Cleaner Production,* Vol. 96, Elsevier, 2015, pp. 569-579.

MyCup (2014). Medical grade silicon vs TPE. Available online at: https://mycup.co.nz/silicone/#:~:text=LSR%20has%20excellent%20tear%20strength%20%28tensile%20strength%29%20LSR,large%20amounts%20of%20pressure%20for%20a%20long%20time. Accessed on February 2022.

Naessens O. and Naessens, J.,Patent: Method for Manufacturing a Menstrual Cup. 2017. Available at: https://patents.google.com/patent/FR3064466A1/en (accessed 29/08/2021).

Naturemade label: https://www.naturemade.ch/en/naturemade-zertifizieren.html (accessed 26/08/2021).

Naturemade (2021). Certification Guidelines, Version 3.1, 1/1/2021: https://www.naturemade.ch/files/Dokumente/Zertifizierung/Richtlinien/Richtlinien_e.pdf (accessed 26/08/2021).

Nealis, C. *Technology and market screening for "green" disposable diapers.* KTH Royal Institute of Technology. Master Thesis, 2021. Available at: https://kth.diva-portal.org/smash/get/diva2:1574756/FULLTEXT01.pdf (accessed 02/08/2021).

Nonwovens Industry, 2020. Trends in the Baby Diaper Market. Available at: https://www.nonwovens-industry.com/issues/2020-01/view_features/trends-in-the-baby-diaper-market/ (accessed 26/08/2021).

Nordic Swan Ecolabel: https://www.nordic-ecolabel.org/ (accessed 26/08/2021).

Nordic Swan. *Nordic Ecolabelling for Sanitary Products*. Version 6.8 • 14 June 2016 - 30 June 2024. Available at: https://www.nordic-ecolabel.org/product-groups/group/?productGroupCode=023 (accessed 27/08/2021).

O'Brien, et al., 'LIFE CYCLE ASSESSMENT: REUSABLE AND DISPOSABLE NAPPIES IN AUSTRALIA', Environmental Engineering, School of Engineering, The University of Queensland, Brisbane, 2009, available at: https://www.readkong.com/page/life-cycle-assessment-reusable-and-disposable-nappies-in-7523826

OCS 100 (Organic Content Standard): https://textileexchange.org/standards/organic-content-standard/ (accessed 26/08/2021).

Official Journal of the European Union. Chapter 6, Miscellaneous manufactured articles, Volume 63, 30 October 2020.

Oil and Gas, 2020. Coronavirus is causing the biggest fall in global energy investment in history: IEA. Available at: https://www.oilandgasmiddleeast.com/drilling-production/36691-coronavirus-is-causing-the-biggest-fall-in-global-energy-investment-in-history-iea (accessed 26/08/2021).

Ökotex 100: https://www.oeko-tex.com/en/our-standards/standard-100-by-oeko-tex (accessed 26/08/2021).

Ökotex, 2020. Tests in menstrual cups for harmful substances. https://www.oekotest.de/kosmetik-wellness/Menstruationstassen-im-Test-Sind-sie-besser-als-Tampons_11183_1.html (accessed 29/08/2021).

Organyc brand: https://organyc.net/organyc-difference/certification/ (accessed 26/08/2021).

Österreichisches Umweltzeichen: https://www.umweltzeichen.at/de/home/start (accessed 26/08/2021).

OVAM, 2018. Gaasbeekot, A., *Potential for circularity of diapers and incontinence material through eco-design*, Danny Wille, OVAM, 2018. Available at: https://ovam.be/sites/default/files/atoms/files/Report%20TWOL%20study%20final-%20EN-%20OVAM.pdf (accessed 26/08/2021).

Pandas by Luvme: https://luvme.eco/products/bamboo-reusable-multi-fit-all-in-one-cloth-nappies (accessed 26/08/2021).

Parliament UK (1990) Environmental Protection Act 1990. Available at: http://www.legislation.gov.uk/ukpga/1990/43/contents (accessed 06/08/2021).

Pastor-Nieto, M. A. and Gatica-Ortega, M.E, 'Ubiquity, Hazardous Effects, and Risk Assessment of Fragrances in Consumer Products', *Current Treatments Options in Allergy*, Vol. 8, Springer, 2021, pp. 21–41.

Peberdy, E., Jones, A. and Green, D., 'A Study into Public Awareness of the Environmental Impact of Menstrual Products and Product Choice', *Sustainability*, Vol. 11, No 2, MDPI, 2019, pp. 473.

PEFC (Programme for the Endorsement of Forest Certification). Available at: https://pefc.org/ (accessed 26/08/2021).

Persistence Market Research, 2021. Tampon Market to Reach USUSD 7.4 Bn Valuation by 2030; e-Commerce Sales Thriving amidst COVID-19 Pandemic. Available at: https://www.persistencemarketresearch.com/mediarelease/tampon-market.asp (accessed 03/08/2021).

Pingo diapers: https://pingo-windeln.ch/?lang=en (accessed 26/08/2021).

Pokhrel at al., 'Acceptability and feasibility of using vaginal menstrual cups among schoolgirls in rural Nepal: a qualitative pilot study', Reproductive Health, Vol. 18:20, BMC, 2021.

Policy Brief, 2020. EU Ecolabel Policy Brief, Absorbent Hygiene Products.

Posch, M., Seppälä, J., Hettelingh, J.P., Johansson, M., Margni M., Jolliet, O., 'The role of atmospheric dispersion models and ecosystem sensitivity in the determination of characterisation factors for acidifying and eutrophying emissions in LCIA', *International Journal of Life Cycle Assessment*, Vol. 13, Springer, 2008, pp.477–486.

Primark, 2021. Period Underwear. Available at: https://www.primark.com/en-ie/periodunderwear?home=true (accessed 30/08/2021).

Rajendran, S., Anand, S. C. and Rigby, A.J., Chapter 5. Textiles for healthcare and medical applications, *Handbook of Technical Textiles* (Second Edition), Volume 2: Technical Textile Applications. Edited by A. R. Horrocks and S. C. Anand, Whoodhead Publishing, 2016.

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.

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), establishing a European Chemicals Agency (ECHA).

Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging (CLP) of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006.

Regulation (EC) No 66/2010 of the European Council and of the European Parliament and of the Council of 25 November 2009 on the EU Ecolabel.

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.

Regulation (EU) 2017/745 of the European Parliament and of the Council of 5 April 2017 on medical devices.

Regulation (EU) 2023/988 of the European Parliament and of the Council of 10 May 2023 on general product safety, amending Regulation (EU) No 1025/2012 of the European Parliament and of the Council and Directive

(EU) 2020/1828 of the European Parliament and the Council, and repealing Directive 2001/95/EC of the European Parliament and of the Council and Council Directive 87/357/EEC.

Report Linker, 2020. *Europe Menstrual Cups Market to 2027 - Regional Analysis and Forecasts by Product Type; Size; Material; Distribution Channel, and Geography*. Available at: https://www.reportlinker.com/p05887364/Europe-Menstrual-Cups-Market-to-Regional-Analysis-and-Forecasts-by-Product-Type-Size-Material-Distribution-Channel-and-Geography.html?utm_source=GNW (accessed 26/08/2021).

Research and Markets, 2020. Insights into the Menstrual Cup Global Market to 2026 - Opportunity Analysis and Industry Forecast. Available at: https://www.globenewswire.com/news-release/2020/07/16/2063125/0/en/Insights-into-the-Menstrual-Cup-Global-Market-to-2026-Opportunity-Analysis-and-Industry-Forecast.html (accessed 30/08/2021).

SAPEA, Science Advice for Policy by European Academies. Biodegradability of plastics in the open environment. Berlin, 2020. doi:10.26356/biodegradabilityplastics.

Schlusaz et al., 2019. Fluff Pulp Performance Improved by Alternative Pine Species. Tappi. Available at: https://www.tappi.org/content/Events/19PEERS/19PEE09.pdf (accessed 26/08/2021).

Scientific Committee on Consumer Safety. OPINION on Fragrance allergens in cosmetic products, 2011. Available at: https://ec.europa.eu/health/scientific_committees/consumer_safety/docs/sccs_o_073.pdf (accessed 26/08/2021).

SCL (Service Commun des Laboratoires), 2019. Available at: https://claripharm.fr/presse/produits-chimiques-protections-hygieniques-quelle-securite-pour-nos-regles/ (accessed 20/09/2021).

Seppälä J., Posch M., Johansson M., Hettelingh J.P., 'Country-dependent Characterisation Factors for Acidification and Terrestrial Eutrophication Based on Accumulated Exceedance as an Impact Category Indicator', *International Journal of Life Cycle Assessment*, Vol. 11, No 6, Springer, 2006, pp. 403-416.

Sharifi-Heris Z., Amiri Farahani L. and Hasanpoor-Azghadi S. B., 'A Review Study of Diaper Rash Dermatitis Treatments', *Journal of Client-Centered Nursing Care*, Vol. 4, No 1, Iran University of Medical Sciences, 2018; pp. 1-12.

Shibly, M. M. H., Hossain, M. A., Hossain, M. F., Nur, M. G. and Hossain, M. B., 'Development of biopolymer-based menstrual pad and quality analysis against commercial merchandise', *Bulletin of the National Research Centre*, Vol. 45, No 50, Springer, 2021.

Silva et al., 'Isothiazolinone Biocides: Chemistry, Biological, and Toxicity Profiles', *Molecules, Special Issue Microbiocides Chemistry*, Vol. 25, No 4, MDPI, 2020, pp. 991.

SIS (Swedish Institute for Standards), Swedish stakeholders request global ISO standards for menstrual products, available at: https://www.sis.se/en/news/swedish-stakeholders-request-global-iso-standards-for-menstrual-products/ (accessed 26/08/2021).

Soil Association Certification: https://www.soilassociation.org/ (accessed 26/08/2021).

Sotelo-Navarro P.X., Poggi-Varaldo H.M., Turpin-Marion S.J., et al, 'Biohydrogen production from used diapers: Evaluation of effect of temperature and substrate conditioning', *Waste Management & Research*, Vol. 35, No 3, Sage, 2017, pp. 267–275.

Spekreijse, J., Lammens, T., Parisi, C., Ronzon, T., Vis, M., Insights into the European market of biobased chemicals. Analysis based on ten key product categories, EUR 29581 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-79-98420-4, doi:10.2760/549564, JRC112989.

Statista, 2020. Baby diapers. Available at: https://www.statista.com/outlook/cmo/tissue-hygiene-paper/baby-diapers/worldwide (accessed 30/08/2021).

Statista, 2020. Estimated market value of sanitary napkins worldwide from 2018 to 2024. Available at: https://www.statista.com/statistics/825098/global-market-value-of-sanitary-pads/ (accessed 30/08/2021).

Struijs J., Beusen A., van Jaarsveld H., Huijbregts M.A.J. (2009). Aquatic Eutrophication. Chapter 6 in: Goedkoop M., Heijungs R., Huijbregts M.A.J., De Schryver A., Struijs J., Van Zelm R. (2009): ReCiPe 2008 - A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation factors, first edition.

Sun, C. (Q.), Zhang, D. and Wadsworth, L. C., 'Development of Innovative Cotton-Surfaced Nonwoven Laminates', *Journal of Industrial Textiles*, Vol. 31, No. 3, Sage Journals, 2002, pp. 179-188.

Super Faiths Inc., n.d., Production of combustible pellets to be used in a biomass boiler. Available at: http://superfaiths.com/english/sfd_04.html (accessed 06/08/2021).

Takaya, C.A., Cooper, I., Berg, M., Carpenter, J., Muir, R., Brittle,S., and Sarker, D. K., 'Offensive waste valorisation in the UK: Assessment of the potentials for absorbent hygiene product (AHP) recycling', *Waste Management,* Vol. 88, Elsevier, 2019, pp. 56-70.

TCF and PCF: http://www.chlorinefreeproducts.org/ (accessed 26/08/2021).

Thaman, L. A. Eichenfield, L. F., 'Diapering Habits: A Global Perspective', *Pediatric Dermatology,* Vol. 31, Suppl. 1, Wiley, 2014, pp. 15–18.

The Green Mark: https://greenliving.epa.gov.tw/newPublic/Eng/GreenMark/First (accessed 26/08/2021).

The Natural Baby Company: https://www.thenaturalbabyco.com/pages/common-materials (accessed 26/08/2021).

The fabric of our lives: https://thefabricofourlives.com/the-benefits-of-cotton/health-wellness (accessed 27/08/2021).

The International EDP® System: https://www.environdec.com/home (accessed 26/08/2021).

Therapeutic Goods, Standard for Menstrual Cups, Order 2018, Therapeutic Goods Order 99, 2018. Available at: https://www.legislation.gov.au/Details/F2018L01546 (accessed 26/08/2021).

Today Kansas, 2020. Cloth Diaper Market Share, Trends, Growth, Sales, Demand, Revenue, Size and Forecast to 2014-2026. Available at: https://todaykansas.com/press/cloth-diaper-market-share-trends-growth-sales-demand-revenue-size-and-forecast-to-20142026/23934 (accessed 26/08/2021).

Tooshies by Tom: https://thetomco.com/our-brands/tooshies/ (accessed 26/08/2021).

TUV Austria, OK Biobased: https://www.tuv.at/en/home and https://www.tuv-at.be/green-marks/certifications/ok-biobased/ (accessed 26/08/2021).

Uddin, F., 'Environmental Concerns in Antimicrobial Finishing of Textiles', *International Journal of Textile Science,* Vol. 3, No 1A, Scientific & Academic Publishing, 2014, pp. 15-20.

Veganok: https://www.veganok.com/en/ (accessed 26/08/2021).

Vegetarian Society (Vegan approved): https://vegsoc.org/contact/ (accessed 26/08/2021).

UNEP, 2016. Global guidance for life cycle impact assessment indicators. Volume 1. ISBN: 978-92-807-3630-4. Available online at: http://www.lifecycleinitiative.org/life-cycle-impact-assessment-indicators-and-characterization-factors/

UN, 2020. Menstrual Cup Specifications. Available at: https://www.ungm.org/UNUser/Documents/DownloadPublicDocument?docId=1085955 (accessed 26/08/2021).

UNEP, 2021. Notten, P., Gower, A., Lewis, Y. *Single-use nappies and their alternatives: Recommendations from Life Cycle Assessments*. United Nations Environment Programme (UNEP), 2021. Available at: https://www.lifecycleinitiative.org/wp-content/uploads/2021/03/UNEP-D003-Nappies-Report_lowres.pdf (accessed 26/08/2021).

UNEP, 2021. Notten, P., Gower, A., Lewis, Y. *Single-use menstrual products and their alternatives: Recommendations from Life Cycle Assessments*. United Nations Environment Programme (UNEP), 2021. Available at: https://www.lifecycleinitiative.org/wp-content/uploads/2021/07/UNEP-LCI-Single-use-vs-reusable-Menstrual-Products-Meta-study.pdf (accessed 26/08/2021).

US FDA, 2020. OBSTETRICAL AND GYNECOLOGICAL DEVICES. Available at: https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?fr=884.5400 (accessed 26/08/2021).

US FDA Premarket Notification System. Available at: https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpmn/pmn.cfm (accessed 29/08/2021).

US FDA MAUDE - Manufacturer and User Facility Device Experience. Available at: https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfmaude/search.cfm (accessed 29/08/2021).

Van Oers L., de Koning A., Guinee J.B., Huppes G. (2002). Abiotic Resource Depletion in LCA. Road and Hydraulic Engineering Institute, Ministry of Transport and Water, Amsterdam.

Van Zelm R., Huijbregts M.A.J., Den Hollander H.A., Van Jaarsveld H.A., Sauter F.J., Struijs J., Van Wijnen H.J., Van de Meent D. (2008). European characterisation factors for human health damage of PM10 and ozone in life cycle impact assessment. Atmospheric Environment 42, 441-453.

Velasco Perez M., Sotelo Navarro, P. X., Vazquez Morillas, A., Espiniosa Valdemar, R. M and Hermoso Lopez Araiza, J. P., 'Waste management and environmental impact of absorbent hygiene products: A review', *Waste Management & Research: The Journal for a Sustainable Circular Economy*, Vol. 39, No. 6, pp. 767-783.

VITO. Griet et al., *Final report MONITORING OF THE BELGIAN MARKET WITH REGARD TO ORGANIC RESIDUES IN TAMPONS SANITARY NAPKINS – Part 2: Target analyses.* Available at: https://www.health.belgium.be/sites/default/files/uploads/fields/fpshealth_theme_file/fps_report_tamponssanitary_pads.pdf (accessed 26/08/2021).

Vizcarra A.T., Liao P.H., Lo K.V., ' A life-cycle inventory of baby diapers subject to Canadian conditions', *Environmental Toxicoly and Chemistry*, Vol. 13, No 10, Wiley, 1994, pp. 1707–1716.

Walker, S. and Rothman, R., 'Review: Life cycle assessment of biobased and fossil-based plastic: A review', *Journal of Cleaner Production,* Vol. 261, Elsevier, 2020, pp. 121158.

Weir, C. S., *In The Red: A private economic cost and qualitative analysis of environmental and health implications for five menstrual products*. Master Thesis, Dalhousie University, 2015. Available at: https://cdn.dal.ca/content/dam/dalhousie/pdf/science/environmental-science-program/Honours Theses/2015/ThesisWeir.pdf (accessed 26/08/2021).

Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E., and Weidema, B., 'The ecoinvent database version 3 (part I): overview and methodology', The International Journal of Life Cycle Assessment, Vol. 21, No 9, Springer, 2016, pp. 1218–1230.

Whitbread L. and Belamant A., The 21 best menstrual cups to buy now if you're looking to try a more sustainable and cost-efficient period product. Glamour Magazine. Available at: https://www.glamourmagazine.co.uk/gallery/best-menstrual-cups (accessed 30/08/2021).

Wiesemann, F. and Adam, R., '14 - Absorbent products for personal health care and hygiene', *Handbook of Medical Textiles,* Woodhead Publishing Series in Textiles, Woodhead Publishing, 2011, pp. Pages 316-335.

WMO (2014). Scientific Assessment of Ozone Depletion: 2014. World Meteorological Organisation. Global Ozone Research and Monitoring Project Report No. 55, Geneva, Switzerland.

Woeller, K.E.; Hochwalt, A. E., 'Safety assessment of sanitary pads with a polymeric foam absorbent core', *Regul. Toxicol. Pharmacol*., Vol. 73, Elsevier, 2015, 73, pp. 419–424.

Woo, J., Kim, S., Kim, H., Jeong, K. S., Kim, E. and Ha E., 'Systematic Review on Sanitary Pads and Female Health', *The Ewha Medical Journal,* Vol. 43, No 3, KAMJE, 2019; pp. 25-38.

Ye, Z., Tang, M., Hong, X. and Hui, K.S., 'Sustainable composite super absorbents made from polysaccharides', *Materials Letters*, Vol. 183, Elsevier, 2016, pp. 394-396.

Yuan, C. et al., 'Comparison of the Effectiveness of New Material Diapers versus Standard Diapers for the Prevention of Diaper Rash in Chinese Babies: A Double-Blinded, Randomized, Controlled, Cross-Over Study', *BioMed Research International*, Vol. 2018, Hindawi, 2018, Article ID 5874184.

Zaghloul, S., El-shafei, A., El-bisi, M., Refaie, R. and Zaghloul, S., 'Herbal Textile Finishes – Natural Antibacterial Finishes for Cotton Fabric', *Egyptian Journal of Chemistry*, Article 1, Vol. 60, Issue 2, NIDOC, 2017, pp. 161-180.

Zampori, L. and Pant, R., Suggestions for updating the Product Environmental Footprint (PEF) method, EUR 29682 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-00653-4, doi:10.2760/265244, JRC115959.

Zero Waste Scotland, *Consumer attitudes towards reusable menstrual products in Scotland*, ZWS, 2019. Available at: https://www.zerowastescotland.org.uk/sites/default/files/Reusable%20Menstrual%20Products%20Research%20Report%20.pdf (accessed 26/08/2021).

60 million consumers, 2019. Available at: https://www.60millions-mag.com/kiosque/tampons-serviettes-cups

List of abbreviations

AHP	Absorbent Hygiene Products
AHWG	Ad-hoc Working Group
AOX	Adsorbable organic halogen compounds
AP	Acidification potential
ASTM	American Society for Testing and Measurement
BAT	Best Available Technology
CAS	Chemical Abstracts Service
CFF	Circular Footprint Formula
CLP	Classification, Labelling and Packaging
CMR	Carcinogenic, mutagenic and reprotoxic
CO_2	Carbon dioxide
$CO_{2, eq}$	Carbon Dioxide, equivalent
COD	Chemical oxygen demand
DQR	Data Quality Rating
ECF	Elemental Chlorine Free
ECHA	European Chemicals Agency
EDC	Endocrine disrupting chemicals
ECOCERT	Organisme de contrôle 6 de certification au service de l´homme et de l’environnement
EDANA	The international association for the nonwovens and related industries
EMAS	Eco-Management and Audit Scheme
EN	European Norm
EP	Eutrophication potential
EPD	Environmental Product Declaration
EU	The European Union
EUEB	The European Union Eco-labelling board
FSC	Forest Stewardship Council

GECA	Good Environmental Choice Australia
GHG	Greenhouse gas
GmbH	Gesellschaft mit beschränkter Haftung (company with limited liability)
GOTS	Global organic textile standard
GPP	Green Public Procurement
GPSD	General Product Safety Directive
GR	Geographical representativeness
GWP	Global warming potential
ISO	International Standardisation Organisation
JRC	Joint Research Centre
LCA	Life Cycle Assessment
LDPE	Low density polyethylene
MSW	Municipal Solid Waste
NaOH	Sodium hydroxide
NaOCl	Sodium hypochlorite
NOx	Nitrous oxides
NGO	Non-governmental organization
NMVOC	Non-methane volatile organic compound
NO_X	Nitrogen Oxides
PAH	Polycyclic aromatic hydrocarbon
PBT	Persistent, bioaccumulative and toxic
PCR	Product category rules
PE	Polyethylene
PEF	Product Environmental Footprint
PEFC	Programme for the Endorsement of Forest Certification
PEFCR	Product Environmental Footprint Category Rules
PET	Polyethylene terephtalate

PLA	Polylactic acid
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
POCP	Photochemical ozone creation potential
PP	Polypropylene
PPWD	Packaging and Packaging Waste Directive
PU	Polyurethane
PVC	Polyvinyl chloride
REACH	Registration, Evaluation, Authorisation and Restriction of Chemical substances
SAP	Superabsorbent Polymer
SFI	Sustainable Forestry Initiative
SO_2	Sulphur Dioxide
SVHC	Substances of very high concern
TCF	Total Chlorine Free
TeR	Technological representativeness
TEWL	Transepidermal water loss
TiR	Time representativeness
TPE	Thermoplastic elastomer
VOC	Volatile Organic Compound
vPvB	Very persistent and very bioaccumulative

List of figures

List of tables

Annexes

Annex 1. Product categories included in ISO 14024 type I ecolabels I related to Absorbent Hygiene Products

Disposable baby diapers		x	x				x	x
Disposable feminine care pads/panty liners		x	x					x
Breast pads		x	x					
Tampons with applicator		x	x					
Tampons without applicator		x	x					
Adult disposable incontinence diapers		x	x					x
Disposable feminine incontinence pads/panty liners		x	x					
Disposable male incontinence pads		x	x					
Bed protection / underpads		x	x					

Reusable baby diapers	x	x			x	x		
Hybrid baby diapers (washable outer cover and disposable absorbent inserts)								
Reusable feminine care pads/panty liners	x	x						
Reusable male incontinence pads	x	x						
Reusable breast pads	x	x						
Period underwear	x	x						
Bed protection / underpads	x	x						
Menstrual cups (reusable)								

Source: JRC.

Annex 2. Absorbent hygiene product categories included in the rest of the identified environmental initiatives

	Processed Chlorine Free / Totally Chlorine Free	naturemade star	VEGANOK	Vegetarian Society Vegan Approved	PEFC	FSC	USDA Certified Biobased Product	ECOCERT	GOTS	OK biobased TÜV Austria	Soil Association Organic	OEKO-TEX STANDARD 100	MADE SAFE	cradletocradle
Disposable baby diapers	x	x	x	x	x	x				x		x	x	
Disposable feminine care pads/panty liners	x		x	x	x	x	x	x	x	x	x		x	
Breast pads	x		x	x	x	x							x	
Tampons with applicator	x		x	x	x	x				x			x	
Tampons without applicator	x		x	x	x	x			x	x	x		x	
Adult disposable incontinence diapers								x						
Disposable feminine incontinence pads														
Disposable male incontinence pads														
Bed protection / underpads												x		

	Processed Chlorine Free / Totally Chlorine Free	naturemade star	VEGANOK	Vegetarian Society Vegan Approved	PEFC	FSC	USDA Certified Biobased Product	ECOCERT	GOTS	TÜV Austria OK biobased	Soil Association Organic	OEKO-TEX Standard 100	MADE SAFE	cradletocradle
Reusable baby diapers									x			x		
Hybrid baby diapers (washable outer cover and disposable absorbent inserts)														x ([50])
Reusable feminine care pads/panty liners									x			x		
Reusable male incontinence pads									x			x		
Reusable breast pads												x		
Reusable period underwear												x		
Bed protection / underpads												x		
Menstrual cups (reusable)			x	x										

Source: JRC.

[50] The disposable inserts are the only nappy product to be certified Cradle to Cradle Silver certification.

GETTING IN TOUCH WITH THE EU

In person

All over the European Union there are hundreds of Europe Direct centres. You can find the address of the centre nearest you online (european-union.europa.eu/contact-eu/meet-us_en).

On the phone or in writing

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

— by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),

— at the following standard number: +32 22999696,

— via the following form: european-union.europa.eu/contact-eu/write-us_en.

FINDING INFORMATION ABOUT THE EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website (european-union.europa.eu).

EU publications

You can view or order EU publications at op.europa.eu/en/publications. Multiple copies of free publications can be obtained by contacting Europe Direct or your local documentation centre (european-union.europa.eu/contact-eu/meet-us_en).

EU law and related documents

For access to legal information from the EU, including all EU law since 1951 in all the official language versions, go to EUR-Lex (eur-lex.europa.eu).

Open data from the EU

The portal data.europa.eu provides access to open datasets from the EU institutions, bodies and agencies. These can be downloaded and reused for free, for both commercial and non-commercial purposes. The portal also provides access to a wealth of datasets from European countries.

Science for policy

The Joint Research Centre (JRC) provides independent, evidence-based knowledge and science, supporting EU policies to positively impact society

EU Science Hub
joint-research-centre.ec.europa.eu

@EU_ScienceHub

EU Science Hub - Joint Research Centre

EU Science, Research and Innovation

EU Science Hub

@eu_science

Publications Office of the European Union