CLEANTEX

Clean and Innovative Textiles Strategy for Circular Economy

MODULE 3
Sustainable Fiber / Material Resourcing

Unit 3.3
Environmental Impact of Sourcing Fibres Worldwide

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In this lecture you will find an overview of environmental impacts of sourcing fibres worldwide, in order to give a perspective of what kind of fibres cause impacts on the environment and which consequences are related with the production of natural and man-made fibres.

The textile and clothing industry covers a wide range of activities, from the transformation of natural or manmade fibres into yarns and fabrics. Several trends have contributed to this increase in consumption. One is the fall in the price of garments in the last few decades. According to a EEA report, between 1996 and 2012 the price of clothing has increased by 3 %, but consumer prices in general have risen about 60 %. This meant that, relative to the EU consumer consumption basket, the price of clothing fell by 36 %. At the same time, the share of clothing in household consumption stayed largely the same: it was 5 % in 1995 and 4 % in 2017. The other significant trend was the rise of fast fashion. Epitomised by multinational retail chains, it relies on mass production, low prices and large volumes of sales. The business model is based on knocking off styles from high-end fashion shows and delivering them in a short time at cheap prices, typically using lower quality materials[1]. Therefore, textile sector has one of the highest Environmental Impact (EI) globally, mainly due to their high carbon emissions and water footprint. Also, the textile is one of the sectors that generates the highest amount of greenhouse gases per unit of material produced, producing one tonne of textiles generates 17 tonnes of CO_2 equivalent[2].

The main fibres are:

- Natural Fibres: are fibres that are produced by geological processes, or from the bodies of plants or animals. They can be used as a component of composite materials, where the orientation of fibres impacts the properties. Natural fibres can also be matted into sheets to make paper or felt[3].
  The most common natural Fibres[5 are]:
    - Cotton is a soft, fluffy staple fibre that grows in a boll, or protective case, around the seeds of the cotton plants of the genus Gossypium in the mallow family Malvaceae.
    - Wool is the textile fibre obtained from sheep and other animals that have wool hair.
    - Cellulosic without cotton are fibres made with ethers or esters of cellulose, which can be obtained from the bark, wood or leaves of plants, or from other plant-based material.

- Man-Made Fibres: Are fibres made from natural polymers which exist in nature, these fibres could be chemically modified but the basis are natural polymers. Therefore, are fibres whose chemical composition, structure, and properties are significantly modified during the manufacturing process[4].
- Man-made Fibres[5]:
    - Polyester is any of a group of polymers that consist basically of repeated units of an ester and are used especially in making fibres.
    - Polyamide is a synthetic polymer made by the linkage of an amino group of one molecule and a carboxylic acid group, including many synthetic fibres such as nylon.

Key points on the environmental impact of fibres worldwide[6] are the following:

- The textile and fashion industry has a long and complex supply chain, starting from agriculture and petrochemical production (for fibre production) to manufacturing, logistics and retail.
- Each production step has an environmental impact due to water, material, chemical and energy use.
- Many chemicals used in textile manufacturing are harmful for the environment, factory workers and consumers.
- Most environmental impacts occur in the textile-manufacturing and garment-manufacturing countries, but textile waste is found globally.
- Fast fashion has increased the material throughput in the system. Fashion brands are now producing almost twice the amount of clothing today compared with 2000.
- Current fashion-consumption practices result in large amounts of textile waste, most of which is incinerated, landfilled or exported to developing countries.

Continuing with the environmental impact of each group, it is defined that the synthetic fibres are commonly seen as "bad" and natural fibres as "good". But this is not always true, when we focus on the production of raw materials, natural fibres have a larger impact on the environment than man-made fibres. Moreover, natural fibres have more impact (especially cotton) in the processes of water use, bleaching, dyeing, printing and finishing. On the other hand, the production of natural fibres tends to use less energy than synthetic fibres[5].

Thus, cotton fibres are the most used natural fibres for textiles and one of the oldest fibres under human cultivation; there are traces of cotton cultivation going back as far as 7,000 years. Conventionally grown cotton fibres are often questioned for the intensive use of pesticides and irrigation during the cultivation, and more sustainable options are requested such as organic cotton, further on we will see the difference between organic cotton and conventional cotton, where 3% of the world's irrigation water use is related to natural fibres and 95% of which is associated with cotton production[1].

The Annual production volume of plant fibres (other than cotton) are important on the market, a wide variety of plant fibres can be found there. Jute is the dominating fibre type which is almost exclusively cultivated in Bangladesh and India. Coir fibres are collected from the coconut plant and is the second largest plant fibre globally. Flax production occurs to a large extent in France and Belgium. When these types of fibres are used as bast fibres, the fibres are extracted from the stem of the plant and subdued to retting. Cellulose fibres are often claimed to be a sustainable alternative to cotton. Since the chemical structure is based on cellulose just as in cotton, there are many similarities in the comfort properties[7].

Regarding animal fibres, it is important to highlight that:

- Wool is a natural renewable fibre and could have been considered an environmentally friendly option. Unfortunately, the extensive sheep farming practised to meet global demand has had huge consequences for the environment. Sheep survive through grazing, which can have a positive impact on certain types of ecosystems when it is well managed. But when land is overgrazed, overgrazing does not allow enough time for vegetation to regrow and can cause the soil to weaken, making it vulnerable to erosion and desertification. Sheep also release methane, a gas that is 25 times worse for global warming than CO_2.[8]
- The production of silk fibre causes a huge environmental impact, it can be attributed to inefficiencies in agricultural infrastructure, specifically electricity supply and irrigation. Climate conditioning for silkworm rearing increases energy consumption. Wastewater is generally discharged to groundwater acting as a low-level pollutant. Silk fibres are a much more valuable textile material than other natural fibres, with very different mechanical properties. Most of the environmental impact of sericulture is related to cocoon production. Embodied solar energy of mulberry leaves and the wood used during cocoon processing account for the majority of R CED. Electricity for cocoon drying and irrigation are the main sources of non-renewable CED. Most GWP100 is related to fertilization and emissions from composting rearing waste. The majority of ecotoxicity impacts result from pesticide use.[9]

The man-made fibres cause several impacts on the environment too, historically, the development of synthetic and regenerated fibres has to a large extent been driven by the high price and uncertainties in the supply of cotton. Here the main challenge is to develop a sustainable production path to substitute the 71 million tonnes yearly produced synthetic fibres that are today fossil-based.

Polyester makes up 82% of man-made fibres and dominates the textile market, followed by polyamide (nylon), polypropylene and acrylics. Further, the microplastics issue is not solved by changing the raw material entering the synthetic fibres.

EI concerns are the contamination of groundwater and process emission with high amounts of heavy metals, manganese salts, sodium bromide, antimony oxide and titanium dioxide. Moreover, Crude oil conversion into petrochemicals releases hazardous toxins into the atmosphere that impact on humans as well as the environment.

Making a simple comparison of the environmental impact between natural fibres and synthetic, the second ones do not seem worse, but it is important to consider other things besides water consumption, energy consumption and CO_2 emissions. Other impacts on the environment are related to the time it takes for the fibre to degrade, and synthetic fibres typically remain in the environment for many more years than natural fibres[7].

Discerning the main man-made fibres e:

- There are several types of polyester fibres, most well-known is polyethylene terephthalate (PET) because a major part of the textile polyester fibres is composed by it. It is a synthetic fibre that is questioned due to its (mostly) fossil resource origin and the release of microplastics. It is the most widely used fibre in the world, mainly in clothing production. Polyester is not bio-degradable and will persist in the ecosystem even when it eventually breaks apart[7].
- Polyamide fibres are also known under the brand name Nylon. There are several types of polyamide fibres with the common denominator being the nitrogen bond. Regarding the Environmental Impact, the production of polyamide fibre emits nitric oxide, this gas is 300 times more potent as a greenhouse gas than CO_2 and 15 times more than methane. This kind of fibres have the same issue as polyester, they are not biodegradable or compostable. The consumption of this type of fibre increases dependence on fossil fuels[7].

The main impacts of the most important group of fibres were defined, to follow them up it is important to provide the methodologies and tools that can measure the EI and then try to find good practices to introduce them in the production chain. Therefore, the key points to consider for the LCA environmental fibres impact are:

- Textile and fashion industry has a long and complex supply chain, starting from agriculture and petrochemical production (for fibre production) to manufacturing, logistics and retail.
- Each production step has an environmental impact due to water, material, chemical and energy use, but the production of raw materials is responsible for a large share of the environmental impact of the textile sector.
- Beyond the type of fibre, the method of fibre production is also of great importance.
- The energy source used throughout the production chain also influences the environmental impact.
- The country of fibre production is important for determining the EI.

Focusing on environmental impact requires a methodological approach, for example Life Cycle Assessment (LCA) Methodology. This methodology was defined in module 2, concretely on unit 2.2 Methodologies & tools. Hereafter the cotton fibre production chain will be described since it is one of the most used fibres in the textile sector, so it will subsequently be described what steps are necessary to determine its impact on the whole value chain.

The stages[10] through which cotton passes from its condition as a raw material to its transformation into fibre are defined below:

- Harvesting & Collection: First, the seeds are collected from the cotton bush, and put them together in packets to be transported to the factory.
- Pre-Cleaning: The cotton is blown to fluff it and soften its fibres, thus getting rid of any remaining impurities.
- Drying: The cotton that is harvested usually has a moisture content of around 5-6 %, however, it then needs to be dried and blended, so it is put into the dryer.
- Ginning machine: Once the cotton is ready, it is fed to the ginning station, where the fibre is extracted from the seed. This stage can be carried out using two technologies, roller or saw ginning machines.
- Post-Cleaning: The lint obtained is cleaned and combed, separating the cotton fibre from a by-product stream of lint. The aim of cleaning the lint is to remove possible impurities in the cotton.
- Pressing: In this last stage, the cotton lint is packed and compacted for storage or transport to the textile mills for further processing into yarn.

Once Cotton fibre production stages have been defined, it is important to know the concept of Comparative LCA, which is often used to determine a better process or product to use. The goal of LCA is to compare the full range of environmental effects assignable to products and services by quantifying all inputs and outputs of material flows and assessing how material flows affect the environment[11].

The impact categories[12] that will be measured are important to know which data it will be:

- Global Warming Potential (GWP): Climate change, measured as global warming potential, is deemed to be one of the most pressing environmental issues of our times. The category indicator results are provided in kg of CO_2 equivalent per functional unit.
- Eutrophication Potential (EP): Eutrophication, also known as over-fertilization, was also chosen for its connection to air, soil and water quality and relevance to agricultural systems. The category indicator results are shown in or PO_4^3 equivalent per functional unit.

- Acidification Potential (AP): Acidification, causing for example acid rain, was chosen because it is closely connected to air, soil, and water quality and relevant to environmental aspects of agricultural systems. The category indicator results are shown in kg SO_2 equivalent.
- Primary Energy Demand (non-renewable) (PED): Primary energy demand from non-renewable sources (e.g. petroleum, natural gas etc.) its relevance to energy and resource efficiency and its interconnection with climate change. The category indicator results are shown in MJ per kg.
- Water Use and Water Consumption (WU and WC): Use of water by human activity. Use includes, but is not limited to, any water withdrawal, water release or other human activities within the drainage basin impacting water flows and quality. Regarding Water consumption, is the water removed from, but not returned to the same drainage basin. Water consumption can be because of evaporation, transpiration, product integration or release into a different drainage basin or the sea. The category indicator results are shown in m^3 per kg.

* Examples of the environmental impacts of fibres or the LCA comparison between conventional cotton an organic cotton can be found in the MOOC presentation and the related recording.

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