↑ Polyester is a by-product of the petroleum industry. While it is not renewable, it is possible to recycle. Currently, most recycled polyester originates from PET bottles and not from recycled polyester textiles.

Environmental Impact of Fibres

by Kirsi Niinimäki

When discussing the **textile lifecycle**, all phases must be considered: fibre cultivation, material manufacturing, yarn spinning, weaving, dying and printing processes, different finishing options, and logistics phases, as well as the use and the end-of-life stages. It is hard to determine which material is best when evaluating the overall environmental impact of a textile, as every material has its own environmental weaknesses. It is also good to remember that natural fibres are not always better than man-made ones. For example, the cultivation of cotton requires intensive consumption of water and large quantities of pesticides and fertilizers. Cotton therefore has a higher environmental impact during its cultivation compared to the production phase of polyester. On the other hand, polyester is a by-product of the petroleum industry and it is not renewable which increases its long-term environmental burden.[1] Polyester production, because of its use of raw fossil materials, has a 63% higher energy consumption than the production of cotton, but the amount of water needed for polyester production is less than 0,1% of water necessary for cotton cultivation.[2]

The cultivation of organic cotton uses less chemicals (pesticides and synthetic fertilizers) than traditional cotton, yet it might consume more water than traditional cotton farming. Although entirely dependent on where the cotton is cultivated, as well as the method of irrigation, research suggests that the water usage in organic cotton cultivation can be up to three times more than in traditional cotton farming.[3] Flax, jute, hemp, and ramie are all plant-based natural fibres that use less water during cultivation than cotton. They are also easily grown crops and need less fertilizers. They grow in nearly all climate conditions and might even be pest-resistant (e.g. flax).[4] Examples of manufactured fibres made out of plant-based raw materials include viscose, cupro and acetate. Polyester, polyamide, acrylic, and spandex are petroleum-based raw materials. The reduction of oil supplies might lead to some problems for the production of petroleum-based fibres in the future, generating the need to further develop new material sources. Regenerated sucrose-based polyesters can be made out of maize or sugar beet.[5] Plant-based fibres are renewable, and in some cases even biodegradable, albeit this is not recommended for textile products. Recently, new more environmentally friendly fibres have been developed to substitute cotton. These include the lyocell fibre *Tencel*, which is a regenerated cellulose fibre manufactured from fast-growing eucalyptus wood using the lyocell process.[6] The lyocell production method is considerably simpler and uses much less energy than the viscose process. As opposed to the toxic chemicals used in the viscose process (p.3.x.x.), non-toxic chemicals are used to manufacture lyocell.

Table 1. Environmental impact of different fibres

Fibre	High environmental impact	Low environmental impact
Cotton	Water and chemical use during cultivation Water consumption during production Use of chemicals in production Waste waters from production Possible use of harmful formaldehyde finish	Low greenhouse gas emissions Renewable, Biodegradable
Linen	Use of chemicals in production Waste waters from production	Low environmental impact of cultivation Renewable, Biodegradable
Wool	Use of Pesticides High methane (greenhouse gas) emissions High ecological footprint (depending on the type of sheep-herding) Use of chemicals (depending on production method) Water consumption during production Waste waters from production	Life-cycle impact (i.a. self-cleaning properties during use phase) Renewable, Biodegradable Excellent fibre for recycling
Viscose	Energy use during fibre production More water use than in polyester production Use of toxic chemicals Waste waters from production Greenhouse gas emissions	No pesticides used Biodegradable Raw materials from renewable sources Less water use than in cotton cultivation
Polyester	High energy use Greenhouse gas emissions Raw materials from non-renewable sources	Low water consumption during fibre production Pesticides are not used Reduced waste water from production Possible to use recycled raw material (PET)
Polyamide (nylon)	High energy use High greenhouse gas emissions Raw materials from non-renewable sources	Pesticides are not used Low waste water from production
Acrylic	Use of chemicals High energy use High greenhouse gas emissions Raw materials from non-renewable sources	Pesticides are not used

↑ The traditional cultivation of cotton is highly water intensive and requires large quantities of pesticides and fertilizers. Cotton picking in Fergana, Uzbekistan.

Furthermore, the process is a closed-loop procedure. This means that all chemicals are reused in the process, which keeps them away from waste waters.[7]

Greenwashing

The use of misleading arguments to highlight environmental benefits that may be entirely untrue, also known as greenwashing, is quite common in the fashion and textile sector. These arguments are adopted to attract consumers who are interested in environmental issues within the textile industry. Bamboo is a good example of the controversial issues in evaluating environmental benefits of textiles. Bamboo is often marketed as an ecological choice but is actually a man-made fibre produced through viscose process, which has a high environmental impact due to its extensive use of water and toxic chemicals. As bamboo grows quickly, it is possible to harvest it several times during the growing period. As well, it is renewable and pest-resistance, and thus in this way better than many other fibres. However, it cannot be claimed to be an eco-fibre because of its harmful industrial process. Bamboo viscose is also a soft material that provides a good hand, a property which however might shorten the use time of the product.

Textile manufacturing processes

Fibres are made into yarns through spinning, which has low environmental impact but may contribute to increased health risks for the workers, for example through dust pollution. Yarns are woven or knitted into textiles, but prior to this stage, yarns are bleached, mercerized, and dyed. These processes can also be done in the fibre form. Starch is applied to the warp yarns during the weaving process, and needs to be washed away from the fabric after weaving. The textiles are then treated with different finishing processes to improve their properties. All these procedures use chemicals and water, and increase the environmental impact of the textile industry. In general, it can be supposed that while aiming for high quality products, more treatments, water, and chemicals are expended.[8] It is estimated that as much as 200 tons of water is consumed to produce a ton of textile , making the textile industry a highly water intensive sector.[9] Furthermore, the textile industries' waste waters are not always appropriately purified from harmful chemicals, especially in developing countries. These chemicals can end up in the water system, enriching in the marine ecosystem and even ending up in the food chain. Chemicals from the textile industry can also pollute ground waters destroying drinking water for large groups of inhabitants. For example, the use of metal complex dyes is forbidden in most Western countries, but they are quite commonly used in developing countries. A recent study identified 72 toxic elements from textile manufacturing. Of these toxic elements, 42 can be purified but only partly in commonly used waste water treatment plants, and 30 elements cannot be treated at all in the current waste water treatment processes.[10] The newest waste water purification technologies are costly and while aiming for savings these technologies are not used in lower cost countries. The considerable and irresponsible use of harmful chemicals is a risk not only for the environment but also for the textile industry workers and even for the end users with toxic chemical remaining in the textiles. As noted, legislation restricts the use of toxic chemicals in textile products in Europe and most Western countries, and textile exporters are responsible that the products meet these regulations.

Closing the loop

Closing the loop indicates that materials can be reused or recycled after their first use phase. The premise is that a product is initially designed to include several life cycles and enable the recycling of all materials at the end of products' life. McDonough and Braungart presented the principles of the **cradle to cradle** approach, which separates the products' end of life path into a biological or technical cycle.[11] The biological cycle, or composting, is not possible for textiles that mix synthetic and natural fibres and include many chemicals. However, technical recycling is possible. This allows separating, or processing materials within the same system. Currently products made from mono-materials, with all layers and parts made of the same material, appear easier to recycle than poly-blend materials or products with mix materials.
Currently much of the research around sustainability is conducted around textile recycling, especially on **upcycling** textile waste into high quality new fibres e.g. as in Trash2Cash project rather than down-cycling textiles into lower value products such as filling materials.[12] In **mechanical recycling** fabrics and yarns are shred and spun into new yarn, which method is traditionally known e.g. in wool and even in cotton recycling. This type of recycling process needs mainly mono-materials. The other option for recycling is **chemical dissolution** and **regeneration of fibres** from old post-consumer textiles. This method can be used on cotton and viscose type fibres as well as polyester. Recycled polyester is already well known, but is currently mainly made out of PET bottles and not from recycled polyester textiles. Producing polyester from waste uses 70% less energy compared to virgin polyester production, but always needs some virgin polyester to maintain the high fibre quality.[13] In general, the challenge in recycling is to keep the fibre quality high, upscale the process to an industrial scope, and to sort and separate the different materials before fibre recycling process. Blends, mostly cotton/viscose and synthetic materials are problematic from a recycling perspective. Only few materials seem to be suitable for chemical recycling and currently nearly all textiles (especially in the garment sector) are made from blends, which are hard or even impossible to recycle. Moving towards a closed loop perspective, we have to critically consider what materials are suitable to be used in the textile industry if all materials and products need to be recyclable.

← Ioncell is a technology that turns used textiles, pulp, and even old newspapers into new textile fibres sustainably and without using harmful chemicals.[14]

Good design, quality according to lifetime

One of the biggest problems in the textile sector is the huge amount of **textile waste** especially in all Western countries. This indicates very short use time of textiles–especially fast fashion–and also low quality. To avoid this, designers are in the key role to choose materials for textiles which are best suitable for their intended use and for the intended lifetime of the product. It is good to remember that the best way to influence the textiles' environmental impact is to extend the use time of a product, which can be done through informed design decisions in two quality levels: technical and aesthetic. Technical quality means attributes and functionalities that are most suitable for the product's predetermined use. High quality products are intended for long use time to avoid early disposal. Here it is advisable to select materials that age aesthetically; product and materials that look good even after long use time. Yet, in some cases it is worthy to estimate the real use time of the product and optimize the product's quality accordingly. It is good to use recyclable materials if the intended use time is average or shorter. Aesthetic quality from the environmental viewpoint signifies not only long-lasting and classical design, but also design which makes the user fall in love with the product and hence establish an emotional bond with the item, which is cherished and maintained well to extend its use time.

See also p. 4.2.

↑ One fifth of water pollution caused by global industry is due to textile dyeing and the synthetic chemicals used in the process. Natural dyes can decrease the environmental impact of dyeing if the mordant chemicals used are non-toxic. Furthermore, plants tie CO_2 through their roots into the soil and can contribute to slowing down climate change. In the Biocolor 2019–2022 project, research is conducted on how natural colours can be used in industrial processes and how design can add eco-luxury values in the context of bio-economy.[15] The photo presents a garment design by Arttu Åfeldt, and textile design by Kirsi Niinimäki.

← This fabric is dyed with old European indigo plant Woad (*Isatis tinctoria*), which is possible to cultivate even in the northern countries. It generates a nice blue natural indigo colour. This photo includes the Woad seed, which also can be used in dyeing.