Petroleum by Nefronus, Wikipedia CC0 1.0 DEED

1.1/ 3 Definition, Classification and Properties of Textile Fibres

This open educational resource has been developed by:

Outi Tuohino
Marja Amgwerd

SusTexEdu

Funded by the Erasmus+ Programme of the European Union

SusTexEdu

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This learning material was developed in the Erasmus+ funded project Education Partnership of Textile and Clothing Sector Materials & Sustainability (SusTexEdu)

The goal of the project is to research and develop education in the textile and clothing sector related to textile materials, sustainability and circular economy.

The learning material has been prepared for piloting, and students will be asked for voluntary feedback after the course for the further development of the material.

Project coordinator: Metropolia UAS

Partners: Hogent (BE), Mome (HU), Omnia (FI), TTHK (EE), TTK UAS (EE), University of Borås (SE)

Funding: Erasmus+

Project period: 2022-2024

About this learning unit (2 ects)

CONTENT DESCRIPTION

- Basic knowledge about definition and classification of fibres
- The structures and properties of different fibres
- The areas of use of different textile fibres

LEARNING OUTCOMES

Student will be able to:

- classificate different textile fibres by origin and chemical structure
- manage the general terms regarding the characteristics and properties of textile fibres
- identify the structures, properties of different textile fibres
- knows different ways how to use textile fibres for different products

STUDENT WORKLOAD

2 ECTS, which is equal to 50-60 hours of work:
for example

- Lectures 26-30 h
- Group activities 6-10 h
- Independent study 10-28 h

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Contents

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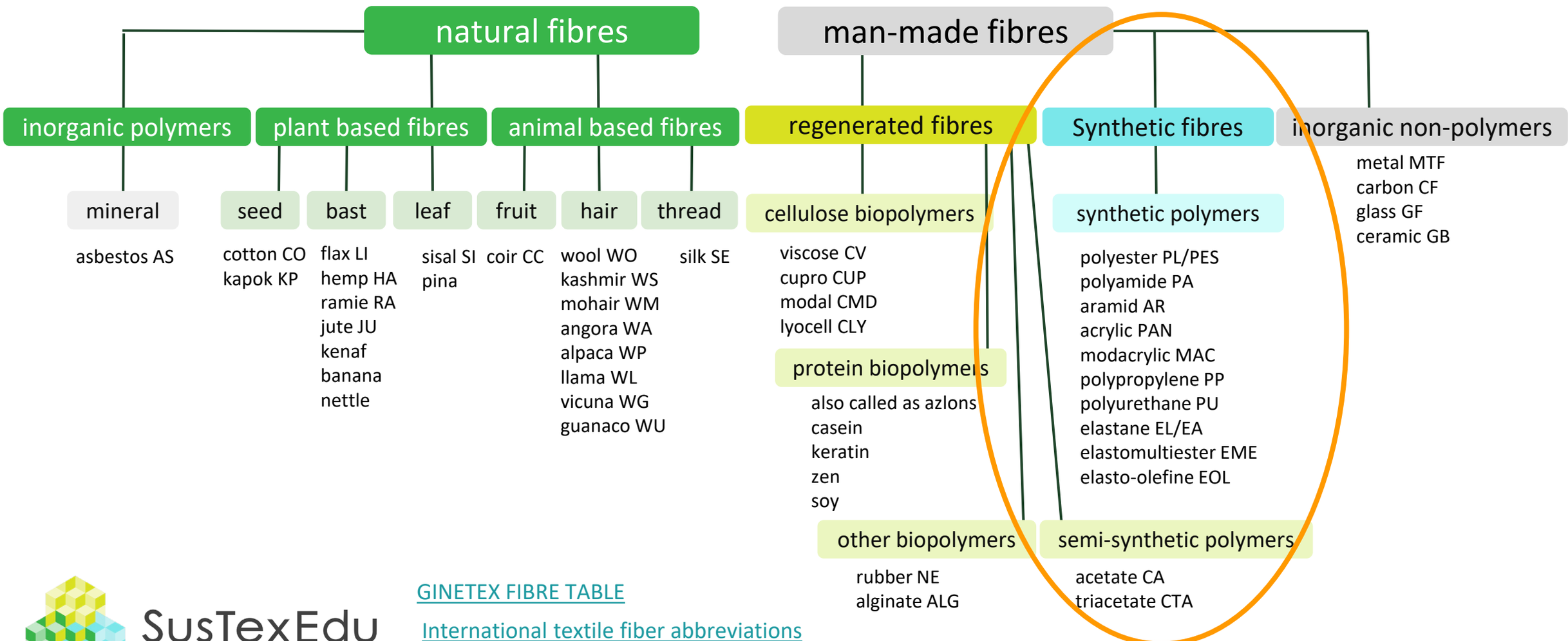
Classification of textile fibres



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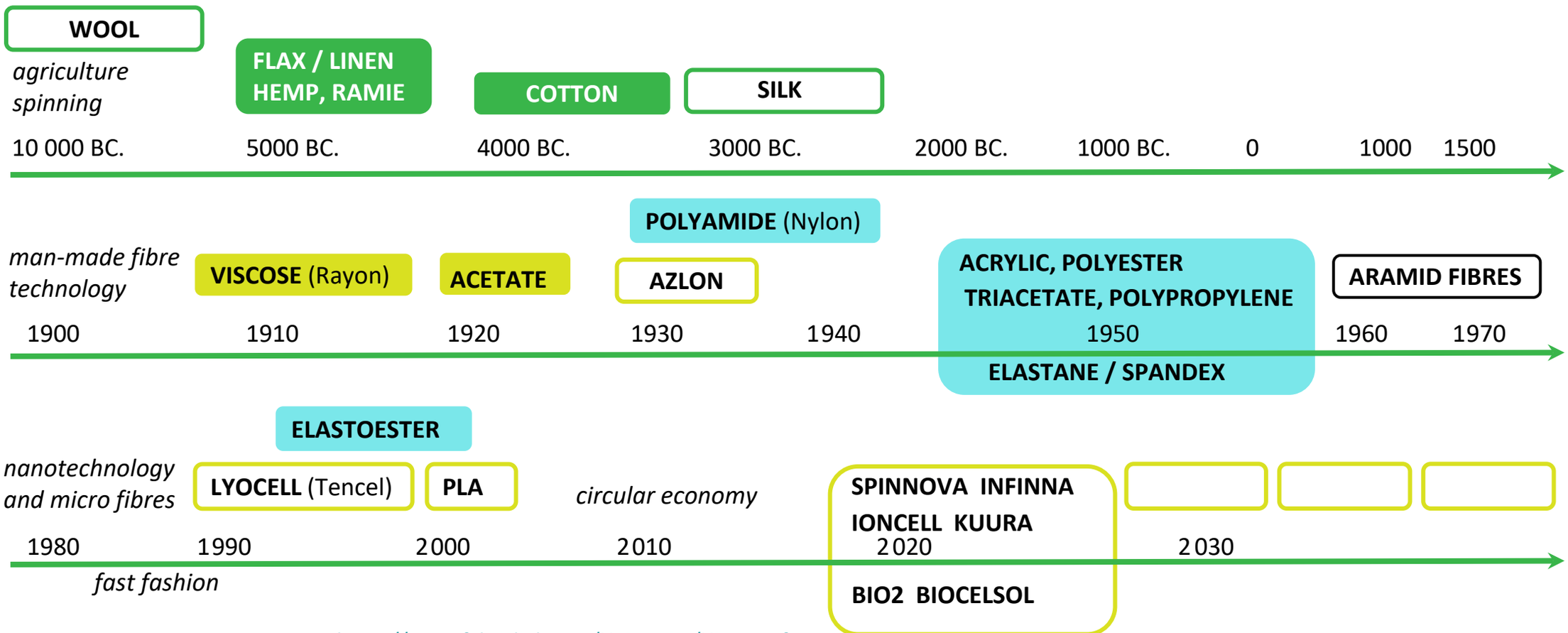
GINETEX FIBRE TABLE

International textile fiber abbreviations

Timeline of textile fibres



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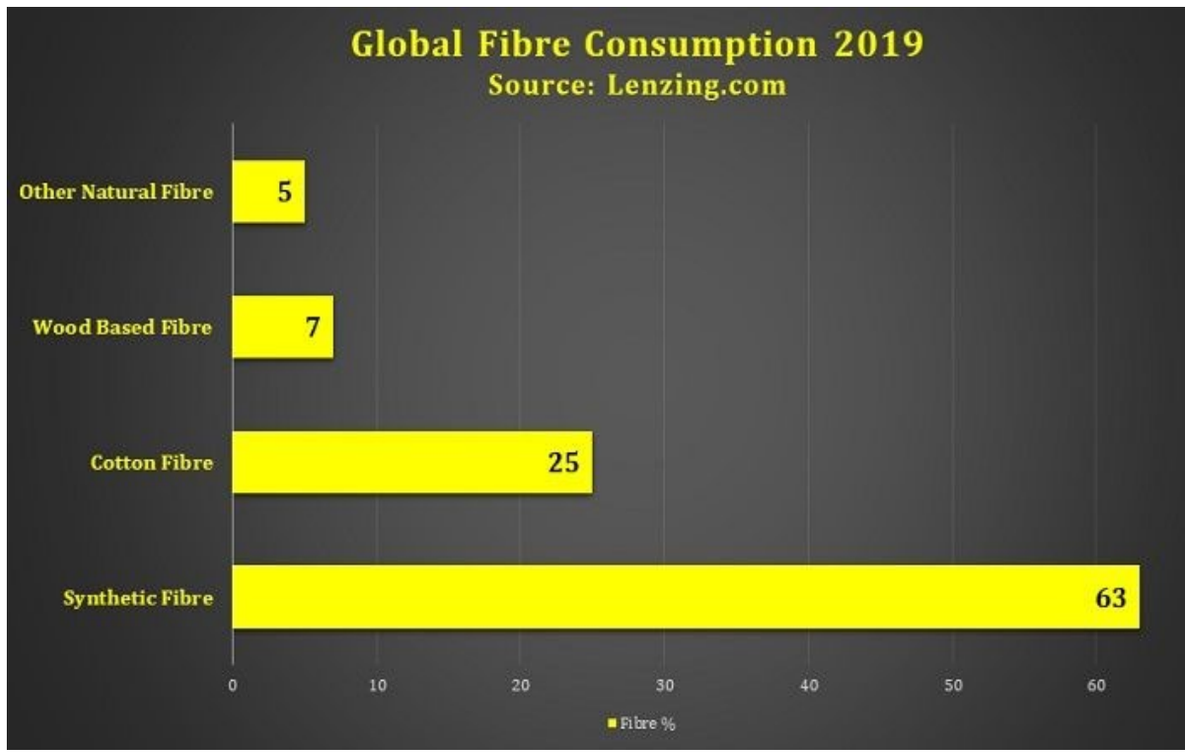
https://www.fabriclink.com/University/History.cfm
https://iwto.org/wool-supply-chain/history-of-wool/
https://heritagecrafts.org.uk/spinning/

Synthetic fibres

- Synthetic fibres are increasing their share of the world's fibre production all the time. The most commonly used fibres are polyester, polyamide, acrylic, polypropylene and elastane.
- *https://www.textiletoday.com*



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Synthetic fibres: petroleum

- Petroleum is an organic nonrenewable source of energy. It took millions of years for it to form.
- Petroleum is a molecular compound containing only carbon and hydrogen.
- Materials made from petroleum are called petrochemicals. Petrochemicals are used for manufacturing synthetic fibres.
- Whether made from recycled or virgin feedstocks, petroleum-based fibres will not biodegrade.

Photos from Wikipedia:
Oil pumbjack in Texas by Eric Kounce, Public Domain
Fuel barrels by Trevor MacInnis, CC BY-SA 2.5 DEED

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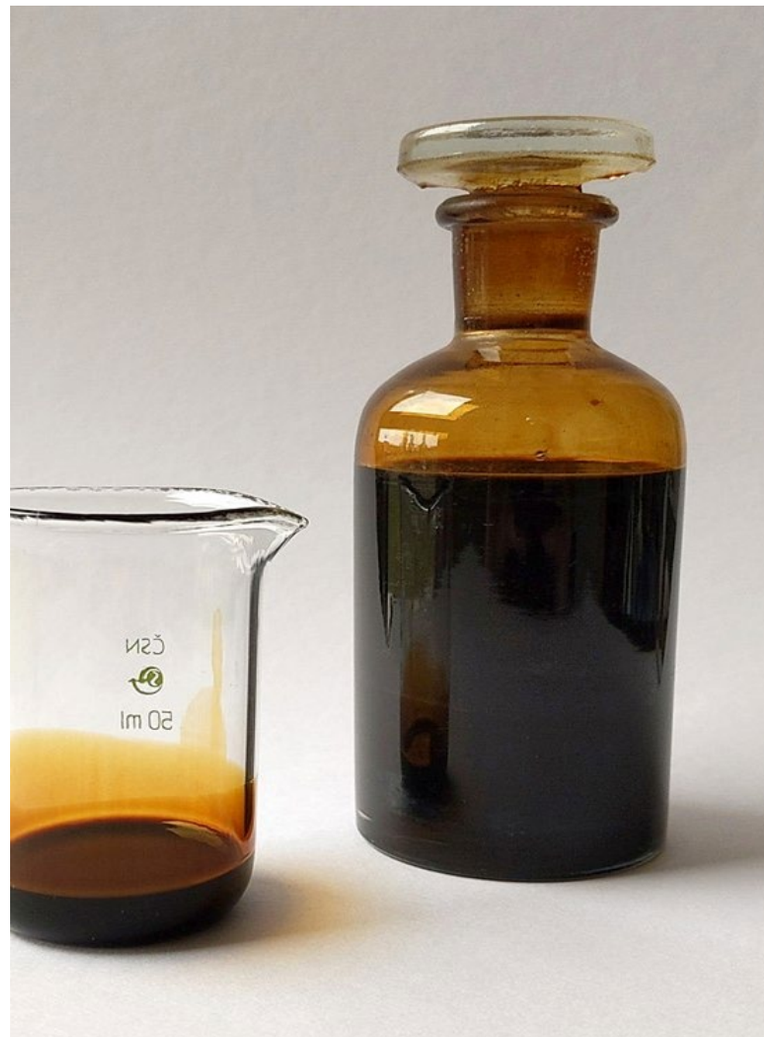
About petroleum in National Geography

Synthetic fibres: polymerization

- Synthetic fibres are produced by synthesizing the raw materials through a process called polymerization, in which continuous filament fibres are created.
- Polymerization is a process in which relatively small molecules called monomers combine chemically to produce polymers.
- The filament fibres produced have uniform quality with many unique properties which can be influenced according to the purpose of use.
- The manufacturing consists of various chemical and physical processes that also may have environmental impact.



Petroleum, photo by Nefronus on Wikipedia CC0 1.0 DEED

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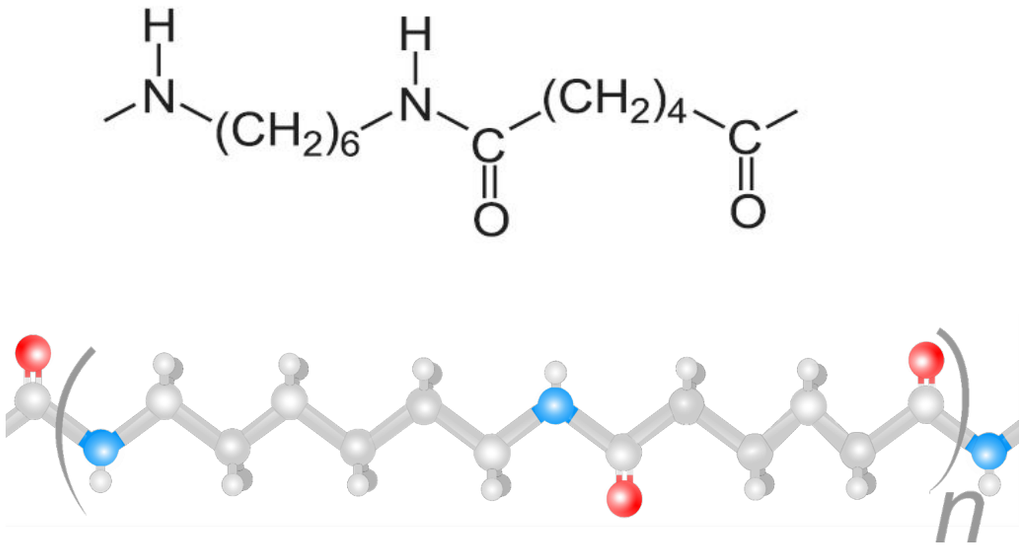
Comparison between Synthetic Fibers and Regenerated Fibers.
T.B. Mutalib on Textilefact.com

Chemical structure of textile fibres

- A textile fibre is made up of molecules arranged in a chain, which in organic fibres consists mainly carbon, hydrogen and oxygen, and often also nitrogen.
- The molecules of each particular compound are arranged in parallel lines in the fibre. This arrangement of molecules is called molecular orientation.
- In synthetic fibres the orientation is even when in natural fibres the orientation may differ in each fibre.



Polyamide 66: image by authors

Chemical composition and molecular structure. Britannica.com

Elemental symbols

The most common chemical elements in textile fibres are:

- Oxygen = O (red)
- Hydrogen = H (light grey)
- Carbon = C (mid grey)
- Nitrogen = N (blue)

Color indication of atoms. Andrey Nagdalian

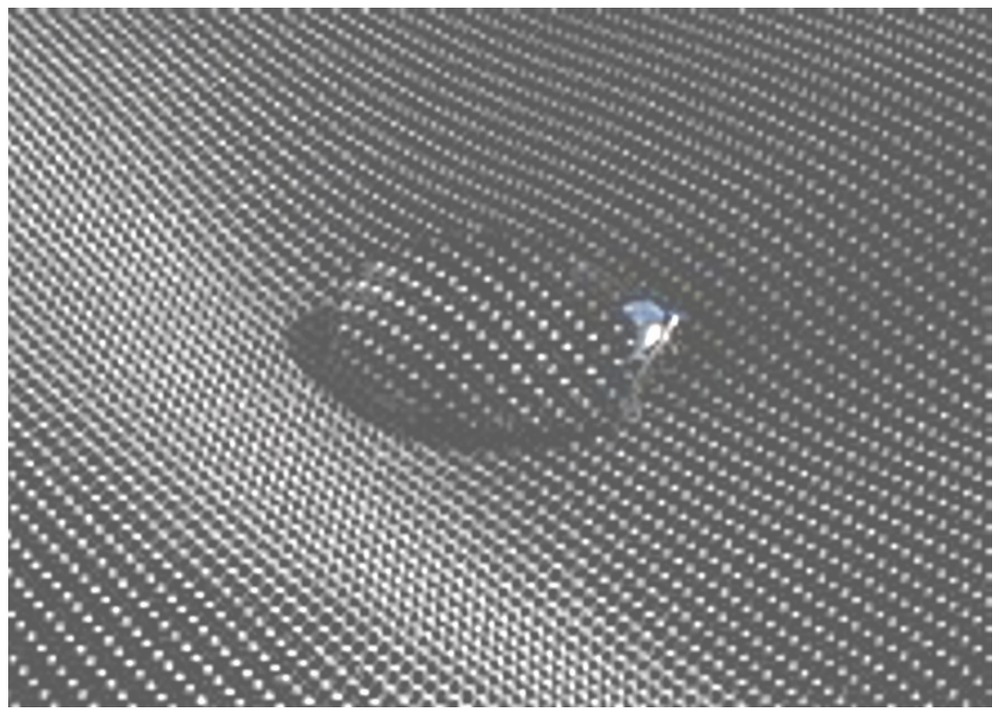
Recyclability of synthetic fibres

- The environmental benefits of recycling synthetic textiles are greater than those achieved by burning textiles.
- Of the recycling methods, mechanical recycling is the cheapest and least environmentally burdensome option. The shortened fibre length and strength is anyway reducing the usage for textiles.
- Other methods as chemical and thermal recycling make it possible recycling of more different fibres and material blends.
  E.g. elastane and coated textiles hinder the recycling process, but chemicals may be used to remove them. Also the fibre quality and length can be modified better suitable for textiles.

Plastic in textiles: potentials for circularity and reduced environmental and climate impacts.
Eionet Report - ETC/WMGE 2021/1
Recycle Textile. Close The Loop

Properties of synthetic fibres

- The common characteristics of these fibres are good strength properties, low moisture absorption and generally easy maintenance. The fibres are easily electrified, gather dirt and become wrinkled.
- The properties of synthetic fibres can be influenced already in the manufacturing phase when building the chemical composition. So, new fibres can always be developed and manufactured for different uses, e.g. extra strong fibres, high temperature resistant fibres, moisture wicking fibres etc.



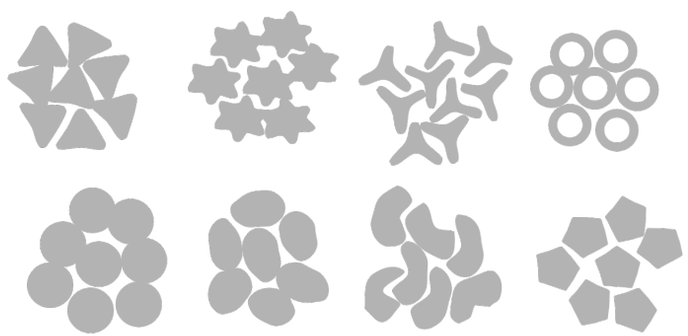
Water repellent polyester, photo by Petar Miloševićf on Wikipedia CC BY-SA 4.0 DEED

Synthetics are fibers made through chemical processes. Textile Exchange

… properties of synthetic fibres

- However, it is still not possible to obtain all the required properties for a particular application due to the inherent nature of these fibres. In these cases, it becomes essential to blend them with other suitable fibres to enhance their properties.
- The target is to improve some properties of fibres and fabrics such as lustre, handle, wicking rate, strength, insulation ability, stiffness and bulkiness.

- Synthetic fibres are generally produced with round cross sectional shapes. Other cross sectional shapes used when spinning the fibre, are e.g. trilobal, triangular, hollow and pentagonal.

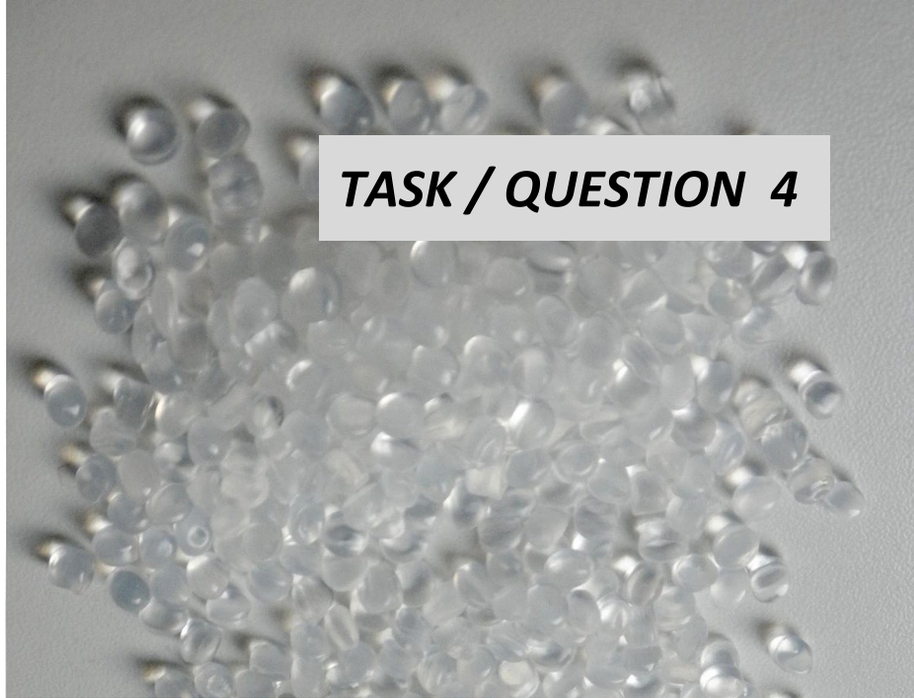


Examples of different cross sections of synthetic fibres. Image by authors

SEM photographs of fiber cross sections by Sukran Kara

Polyester (Pes)

- Polyester is the most produced textile fibre in the world. The main producer is China, also India, Taiwan, South-Korea and USA produce polyester.
- Trade names of Pes are e.g. *Crimplene, Coolmax, Dacron, Diolen, Terylene, Thermastat, Thermolite, Trevira*
- There are many different types of polyester. The most important type is polyethylene terephthalate (PET), commonly referred to simply as polyester.



Polyethylene balls, pohoto by Lluis tgn on Wikipedia CC BY-SA 3.0 DEED
Polyester staple fibres, photos by authors

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Polyester Fiber. Handbook of Textile and Industrial dyeing 2011

Properties of Polyester

- Polyester is a quite strong fibre.
- It does not wrinkle much and straightens itself.
- It stands sunlight well but insulates heat poorly.
- It gets static easily. Antistatic properties can be obtained with e.g. carbon or metal fibres.
- The finest micro fibres are made from filament fibres. By modifying polyester fibres, special fibres are obtained, e.g. extra-strong, curly, shrinkable, anti-pilling, profiled, fireproof and hollow fibres.

Polyester fleece, photo by iPowahFX Studio on Wikipedia CC BY-SA 4.0

Characteristics of polyester. Fabricklink.com

The use of Polyester

- Polyester is much used beside pure, also in blends to improve the properties of natural fibres or to reduce the wrinkling and shrinkage of cellulose fibres. New functional technical materials are also constantly being developed from it.
- The possibilities of using polyester are versatile, it is used both for light innerwear and also for outdoor and technical sportswear fabrics. It is also used for interior textiles.
- As a staple fibre, polyester is used for waddings and upholstery.

Polyester shirt, photo by Antimoni on Wikipedia CC BY-SA 3.0

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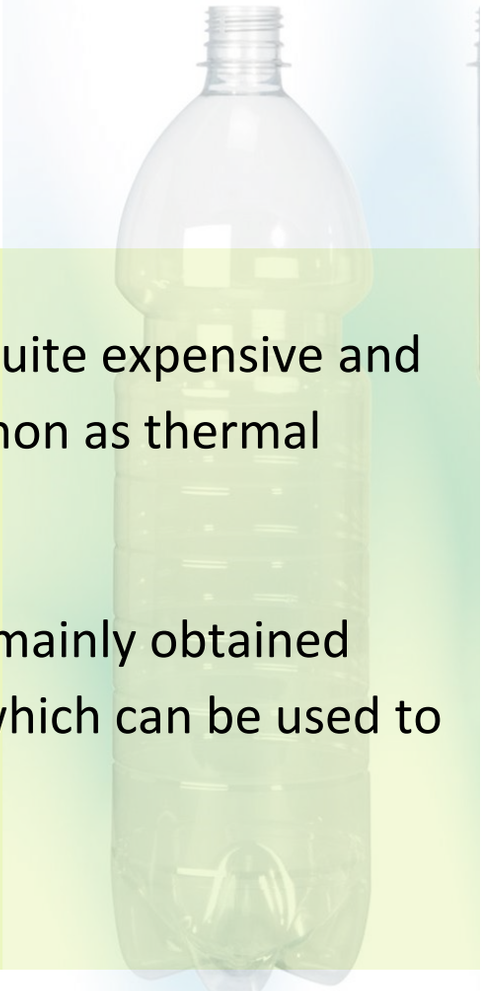
The recyclability of Polyester

- In thermal recycling polyester products are first mechanically crushed or torn and after melted and reprocessed into fiber. The carbon dioxide emissions of thermally recycled polyester are about one third of the emissions of virgin polyester.
- In chemical recycling plastic molecules are breaken up and reforming them into yarn.

Chemical recycling is quite expensive and therefore not as common as thermal recycling.

- Polyethylene (PET) is mainly obtained from plastic bottles, which can be used to make polyester fibre.



PET bottle by Nicole Gordine*, Wikipedia CC BY-SA 4.0*

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Sustainable Recycled Polyester in Textile. M.I.Kiron. Textile Learner

Sustainability Science: Ensuring Recycled Polyester Claims Are Genuine. Sourcing Journal

Polyester is the most used textile fiber in the world. Textile Exchange

Polyamide (Pa)

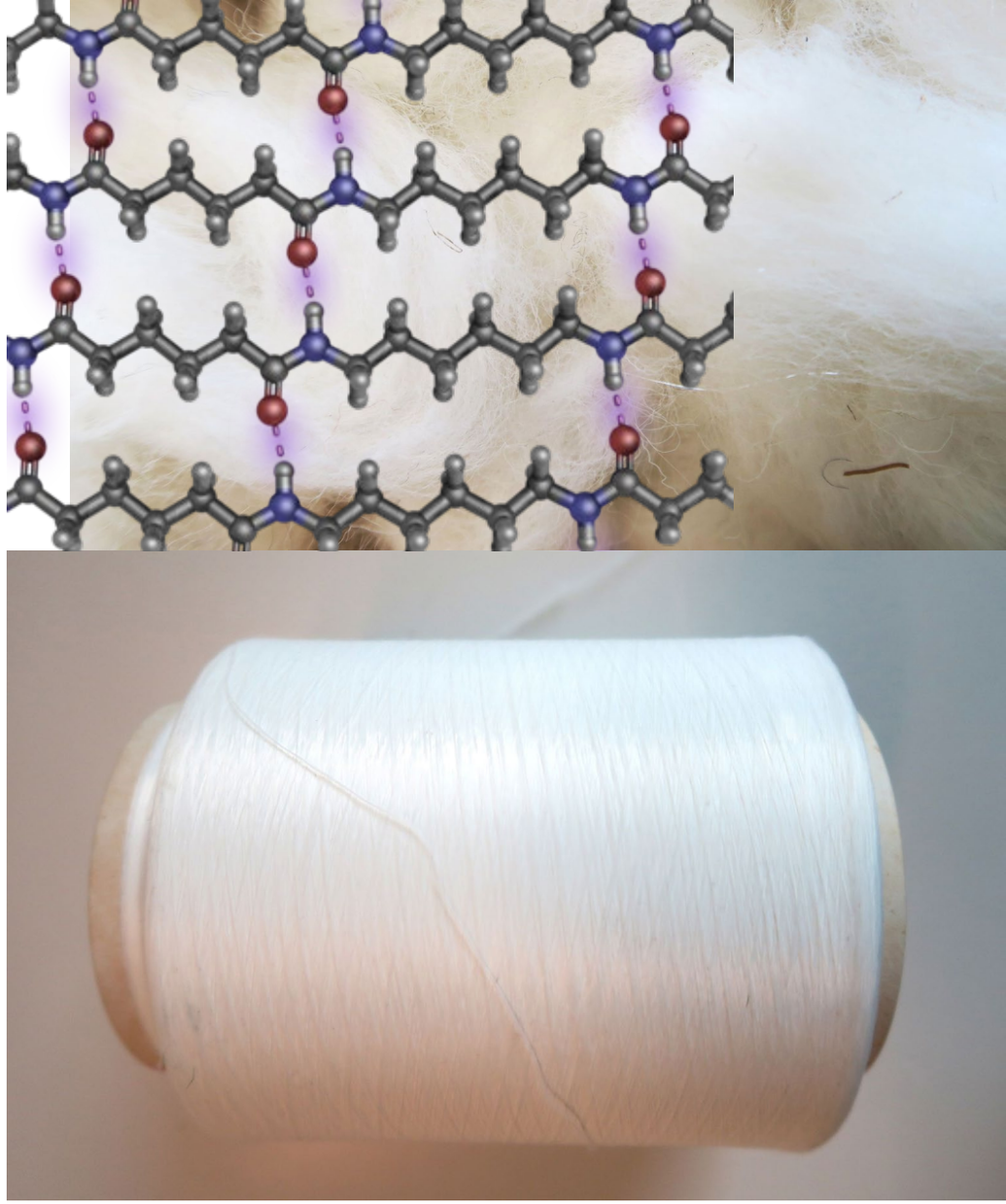
- Polyamide was the first fabric made entirely in a laboratory. It became available around second world war and was used for military products and as a silk replacement for items like stockings.
- Tradenames e.g.: *Nylon, Tactel, Cordura, Meryl, Perlon*
- The main producer of polyamide is China, which produces about 70 percent of all the world's polyamide. Polyamide is also produced e.g. in the United States and Taiwan.

Nylon was first synthesized by Wallace Carothers at DuPont in 1930s. Photo: Wikipedia, Public Domain

Nylon. Britannica.com

Polyamide fibre

- Polyamide is a straight-chain macromolecule with a repeating -CO-NH- amide bond.
- There are many polyamides and they are distinguished from each other by marking the number after the abbreviation, which indicates the number of carbon atoms in the starting materials in question.

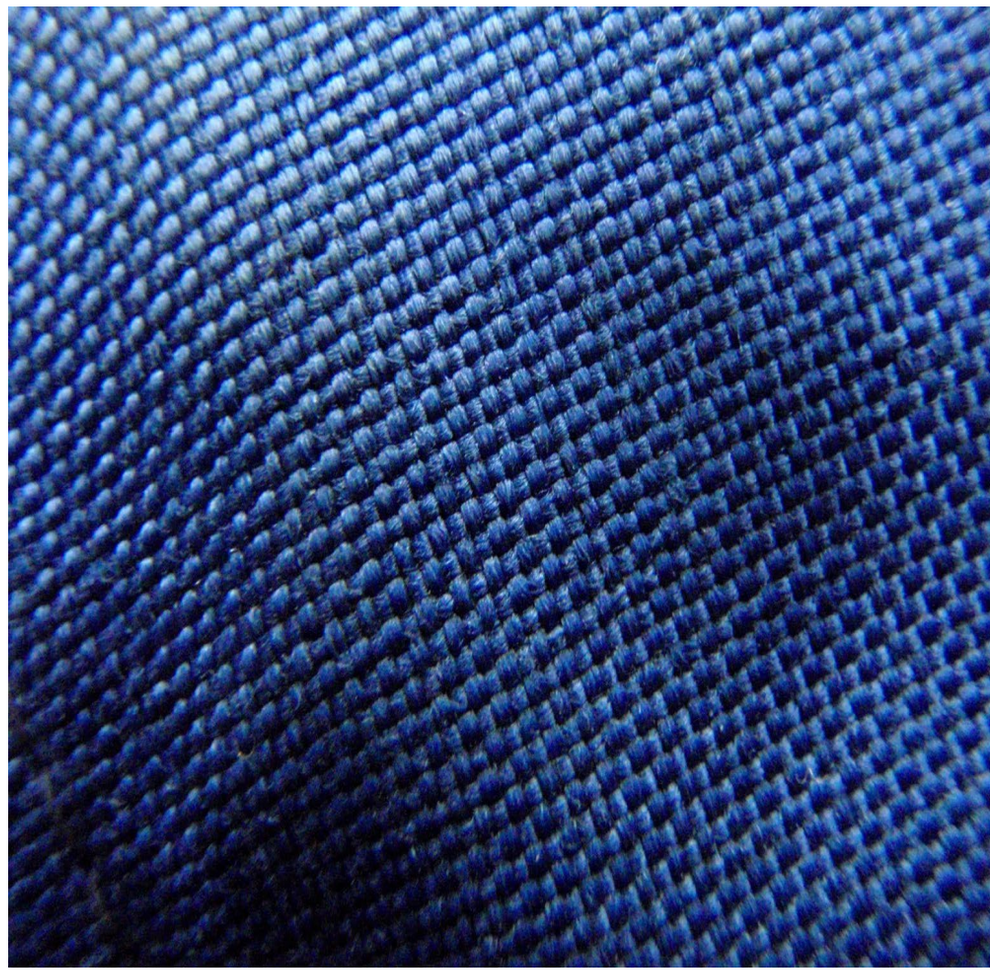


Hydrogen bonding in nylon 6-6,
photo by Yassine Mrabet, Wikipedia CC BY 3.0 DEED
Polyamide staple and filament fibres, photos by authors

Recycling and Degradation of Polyamides.
L.Zheng, M.Wang, Y.Li, Y.Xiong, C. Wu. 2024

Properties of Polyamide

- Polyamides are dense and smooth fibres, they
  - are very strong
  - insulate heat poorly
  - are easily electrified
  - are weakly resistant to the sun's UV radiation and weather changes.
- The properties of polyamide as synthetic fibre can be influenced during the fibre manufacturing phase, and by modifying it the properties can be improved.



Cordura (trade name), photo by Apapadop on Wikipedia, CC BY-SA 3.0 DEED

SusTexEdu [Characteristics of Nylon.](#) Fabric link

The use of Polyamide

- Polyamide is usually used in clothes to increase abrasion resistance and strength. It suits well as a raw material for outdoor clothing, socks, sails and various bags, for ropes and traction belts.
- Microfibres have expanded the possibilities of using polyamide in clothing fabrics since the 1990s.

Polyamide softshell coat, photo and design by authors.
Polyamide sail, photo by Malcolm Morley on Wikipedia, Public domain.

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Properties of fibers and fabrics that contribute to human comfort
S.A. Hosseini Ravandi, M. Valizadeh 2011

The recyclability of polyamide

- Polyamides are recyclable. The waste used can either come from pre-consumer cut waste or post-consumer waste such as clothing and materials like industrial fishing nets.
- Nonetheless, the recycling processes of polyamide – whether chemical-based or mechanical-based – continue to have their disadvantages; the chemical process uses hazardous chemicals while the mechanical process is water-intensive.

A fishing net in Brandon Creek,
photo by Peter Church, Wikipedia CC BY-SA 2.0

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Sustainability of Nylon. Sustainable Fashion
How companies can source nylon more sustainably. Textile Exchange

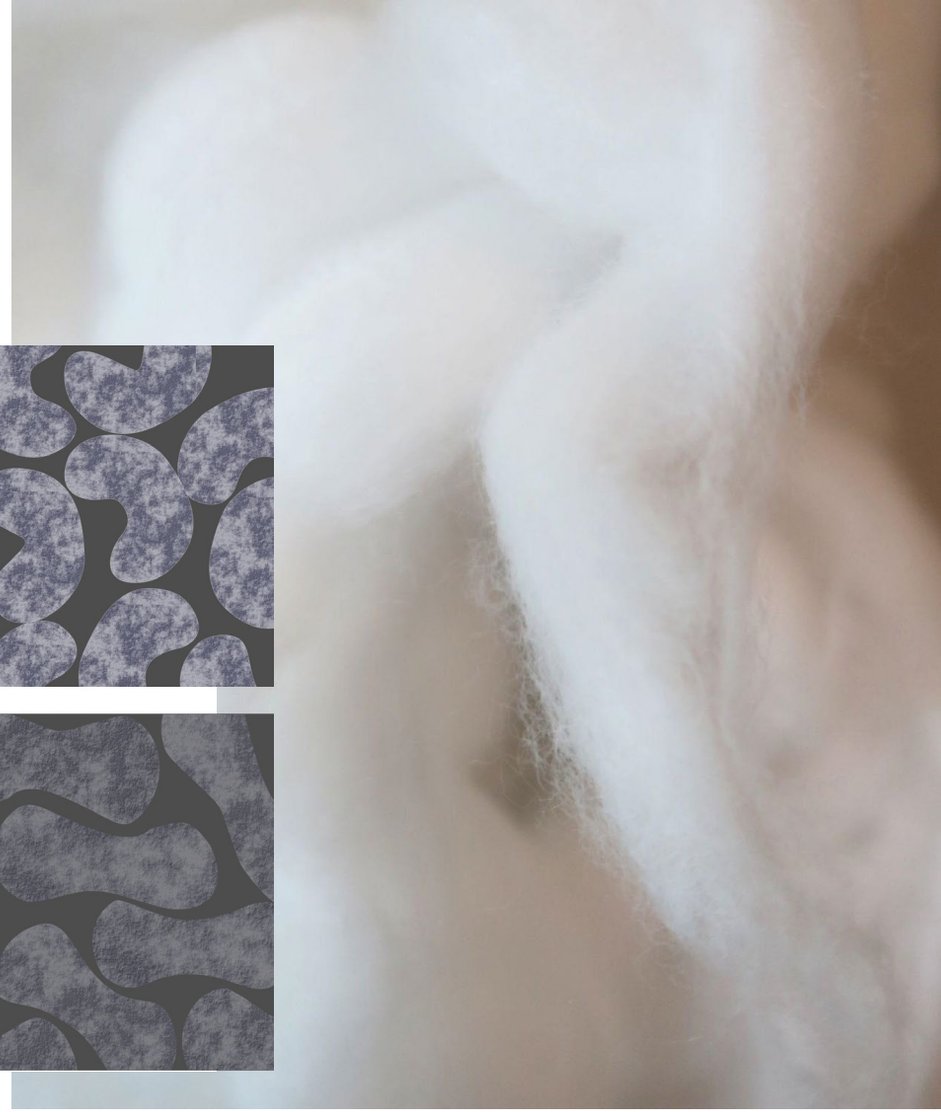
Acrylic, polyacrylic (AC)

- DuPont developed the first acrylic fibres in 1941 under the trade name Orlon. The production of larger quantities started in the 1950s. It also has other trade names, e.g. Acrilan and Creslan.
- In 2020, the share of the total production of acrylic fibres was around 1%. The production volumes have steadily decreased in recent years. Its most important producing country is China. Other important producing countries are Turkey, Japan and India.

Acrylic yarn, photo by Rajeev Vasudev on Wikipedia CC BY-SA 4.0

Acrylic fibre

- Acrylic fibres are made of polyacrylonitrile polymer. Acrylic has several unique properties. It is highly resistant to UV radiation as well as mold and micro-organisms.
- Due to their structure and resiliency, acrylic fibres can also be made to resemble other fibres such as wool.



Acrylic staple fibre, photo by authors
Cross sections of acrylic, kidney and dogbone shape structures. Image by authors

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Major fibres and their properties Acrylic Fiber - an overview | ScienceDirect Topics
Properties, Manufacturing and Uses of Acrylic Fibre. Textile Engineering 2023

Properties of Acrylic

- Acrylic is strong, light, soft, fluffy and warm. The dimensional stability and color fastness is good. The duration of consumption is reasonable.
- Acrylic is usually suitable for people with allergies.
- On the downside, acrylic are extremely prone to pilling, although there are are also anti-pilling acrylic in the markets.

Acrylic beanie, photo by Sari Jantunen / Lusto (The Finnish forest museum) on Finna.fi, CC BY 4.0

The use and recyclability of Acrylic

- Acrylic is used mainly as staple fibres.
- Acrylic can be mixed with e.g. for wool, cotton and polyester.
- In addition to knitwear, acrylic is used for faux fur, blankets, outerwear fabrics and interior fabrics.
- The linings of boots and gloves are also made from acrylic fibre.
- Acrylic textiles can be recycled chemically back to acrylic polymers. The method is not widely in use yet.

50% acrylic 50% wool beanie, photo by authors

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Acrylic Textile Waste Recycling. Shimi Research Center

Polypropylene (PP)

- The production of the fibre was developed in Italy in 1950s. The production of polypropylene is cheap and fast, and it has increased the most of all fibres recently (about 3% of world textile fibre markets 2020).
- Nowadays polypropylene is produced all over the world, mostly in China and in the United States.
- Trade names of polypropylene are e.g. *Alpha, Meraklon, Thinsulate, Typar* and *Ulstron*

PP staple fibres, photo by Henan Botai Chemical Building Materials Co., Ltd on Wikipedia CC BY-SA 3.0

The History of the Development of Melt Blowing Technology By John G. McCulloch Ph.D.

Properties of polypropylene

- Polypropylene is a light and strong fibre.
- It has resistant to chemicals but poor resistant to sunlight.
- Its permeable to water and insulates heat well.
- The fibre can be dyed poorly and earlier the fibers were mass-dyed as coloring, but nowadays pigment colors can be used.
- Polypropylene is not biodegradable, but is completely recyclable. Polypropylene waste does not produce toxic or harmful by-products.

Baby diapers by Delipap Oy.
Photo: Lusto (The Finnish Forest Museum)
on Finna.fi CC BY 4.0

Polypropylene Fiber: Properties, Manufacturing Process and Applications. M.I. Kiron 2013
Envionmental impacts of polypropylene (PP) production and prospects of its recycling in the GCC region.
A. Alsabri, F. Tahir, S.G. Al-Ghamdi 2021

The use of polypropylene

- Polypropylene can be used versatilely both for clothing and interior textiles and for technical purposes.
- Nonwoven, as hygiene and operating room textiles are made from polypropylene.
- The fibre works well also for clothing due to its heat insulation. Sports underwear, outdoor clothing and knitwear and sleeping bags are much made from it.
- Polypropylene is also used for products as ropes, belts, lifting belts, support fabrics, non-woven fabrics, geotextiles and carpets.

"Thermal underwear", image by authors. Gloves with Thinsulate, photo by Villy Fink Isaksen on Wikipedia CC BY-SA 4.0

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Polyurethane (PU)

- Polyurethane is a synthetic polymer, which exists in various forms. It can be modified to be either rigid or flexible.
- It is mostly used for the production of foam rubber and in the textile and clothing industry, e.g. for waterproof coatings.
- It is also used as a textile fibre, e.g. in elastane.

Photos from Wikipedia:
Waterproof PU coated children wear by Transendola, CC BY-SA 4.0
Thermoplastic PU chips by Luigi Chiesa, CC BY-SA 3.0
Polyurethane foam exposed to UV light. Apparent is the discoloration that occurs over time. Photo by Cottontails, CC BY-SA 4.0

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The processing, structure and properties of elastomeric fibers.
J.U. Otaigbes, A. Madbouly 2009

Elastane (EL)

- Elastanes are two-component polymers, a blend of at least 85% polyurethane and polyethylene glycol that is known for its great elasticity, strength, and durability.
- Elastane is an elastomer, which means it can be stretched to a certain degree and it recoils when released. Elastane fibres can be stretched to almost 500% of their length.
- Elastomers can be chemically recycled.

Elastic cycling wear, photo by Adenosine Triphosphate on Wikipedia CC BY-SA 4.0 DEED

Physical Properties of Lycra Fiber. T.B. Mutalib
Spandex Fiber: Properties, Manufacturing Process and Uses.
Md. Reazul Islam 2021

Elastomultiester (EME) and **Elasto-olefin** (EOL)

Other types of elastomeric fibres include e.g: Elastomultiester fibres and a few types of polyolefin fibres. They are used as alternative to elastane to give elastic properties to the final product.

- **Elastomultiester (EME)** is a bicomponent fibre formed by two different polymers, which form a spiral structure. The fibre has at least 85% esters.
- Its elasticity is at least 1.5 times (50%), i.e. less than with polyurethane.
- Elastomultiester (EME) with trade name *Lycra T400* is used e.g. in denim fabrics. “More than 65% of the LYCRA® T400® EcoMade fibre come from recycled plastics and renewable plant-based resources.”

Denim fabric , photo by Thegreenj on Wikipedia GDFL

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Elastomultiester on Commonshare

Fibre Labelling. Elastomultiester - DuPont. JRC Publications Repository 2011

Elastomultiester (EME) and **Elasto-olefin** (EOL)

- **Elasto-olefin (EOL)** consists of at least 95% by weight of macromolecules that are made from ethylene and at least one other olefin. Its elasticity is at least 1.5 times (50%).
- Advantage is the high heat resistance, so EOL can be used e.g. for hospital wear, that need high temperature washing (75C-100C).
- Its trade name is e.g. *XLANGE*.

Hospital wear, photo by Adenosine Triphosphate on Wikipedia CC BY-SA 4.0

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Original EOL New Generation Elastic Fiber | XLANCE®.
China Textile Leader / News 2023

Aramid (AR)

- Aramids were developed from polyamides by modifying them into fibres suitable for fire protection. They are aromatic polyamides, which:
  - have low flammability and very high melting point (>500 °C)
  - are non conductive and have good resistance to abrasion and organic solvents
  - are sensitive to acids, salts and UV radiation
- Trade names of aramid are e.g. *Nomex, Kevlar and Twaron.*

Aramid fabric, photo by No-w-ay on Wikipedia CC BY-SA 4.0
Kevlar staple fibre, photo by Cjp24 on Wikipedia CC BY-SA 3.0

Aramid fibers. M. Ertekin 2017

The use of Aramid

- Aramid fibres are used e.g. as a reinforcing fibre and in protective clothing that requires special strength and wear resistance.
- For example, firemen's protective suits have aramid fibres because they can also withstand very high temperatures.
- Aramids are also used for ropes, cables, belts and reinforcements for various purposes, e.g. for protective footwear and gloves, car tires and bulletproof vests.
- It is also used to make composites for aircraft structures.

Firemen at work, photo by AMagill on Wikipedia, CC BY 2.0

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Other synthetic fibres

- **Fluoro fibre (PTFE)** is used e.g. for membranes as Gore-tex for outdoor use. Such membranes are breathable and waterproof. Main use is for technical products as filters. Polytetrafluoroethylene is also known with a trade name Teflon.
- **Chloro fibre (CLF)** is also called polyvinyl chloride (PVC), both used as fibres and waterproof coatings.
- **Polytethylene (PE)** is a polyolefin fibre consisting more than 85 % olefin units. The fibre is very strong and light, use for technical textiles and other products.
- **Polyactide** is a bio-based synthetic fibre consisting at least 85% polylactic acid. Fibre is obtained from plants and formed into lactic acid.

PTFE: Synthetic fluoropolymer fiber on Fiberline.com
Chlorofibre: Properties, Uses and Advantages. M.I.Kiron 2013
High Performance Polyethylene Fibers – An Overview. M.I.Kiron 2016
Biopolymers in Textile Processing Industry. Asim Kumar Roy Choudhury

Identification of textile fibres with a burning test

- **Cellulose fibres** (e.g. cotton, linen) burn constantly with light grey smoke, don't melt or shrink, smell like burning paper, and leave grey feathery ash.
- **Proteins** (e.g. wool, silk) burn slowly, curl away from the flame, smell like burning hair and leave crushable black ash.
- **Acrylic** melts and burns, moves away from the flame, with a chemical smell and leaves a black, brittle hard bead.
- **Polyester** melts and burns, with a sweet smell and leaves a hard, black bead.
- **Polyamide** melts and burns, with a celery smell and leaves a hard, grey, tan bead.
- **Elastane** melts and burns, with a chemical smell and leaves soft, black ash.

Photo by Осадчая Екатерина, Wikipedia CC BY-SA 4.0 DEED

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Burn test / FabricLink Identification of textile fibres / The Textile Journal

Assignments and topics

1) What does nanotechnology mean? etc. questions and topics that may open the development of textile materials to students at a general level.

2) What are carbon and hydrogen? What problems, challenges the use of petroleum has?

3) For which purposes recycled synthetic textiles can be used?

4) What means trade name?

5) Use and properties of 3 different types of polyamide fibres (as Cordura)?

6) What might have caused the decline in acrylic production?

7) Experiences of acryl textiles?

8) When a fibre can be called elastic?

9) What sustainable aspects can you find from elastane, elastomultiester and from elasto-olefin?

10) Burning test to all fibres

Learning material

Books: e.g.

- Textiles and Fashion Materials, Design and Technology. Part 1: Fibre Types. Rose Sinclair 2014
- Handbook of Textile Fibres Vol 2 - Man-Made Fibres. J.Gordon Cook 1984

Learning material online: e.g.

- Plastic in textiles: towards a circular economy for synthetic textiles in Europe. European Environment Agency 2021
- Man-made fiber. J.Preston. Britannica.com
- Textiles for Circular Fashion. Paulien Harmsen, Wouter Post, Harriette Bos. Wageningen University & Research 2022 PDF
- Synthetics are fibers made through chemical processes. Textile Exchange
- Textile Fibers © 2013 Cotton Incorporated PDF
- International textile fiber abbreviations
- "Textile University" by Fabriclink

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Tips for learning more

Fiber in the page of Textile Learner

The end of petrochemical-based fabrics? Debra Cobb 2022

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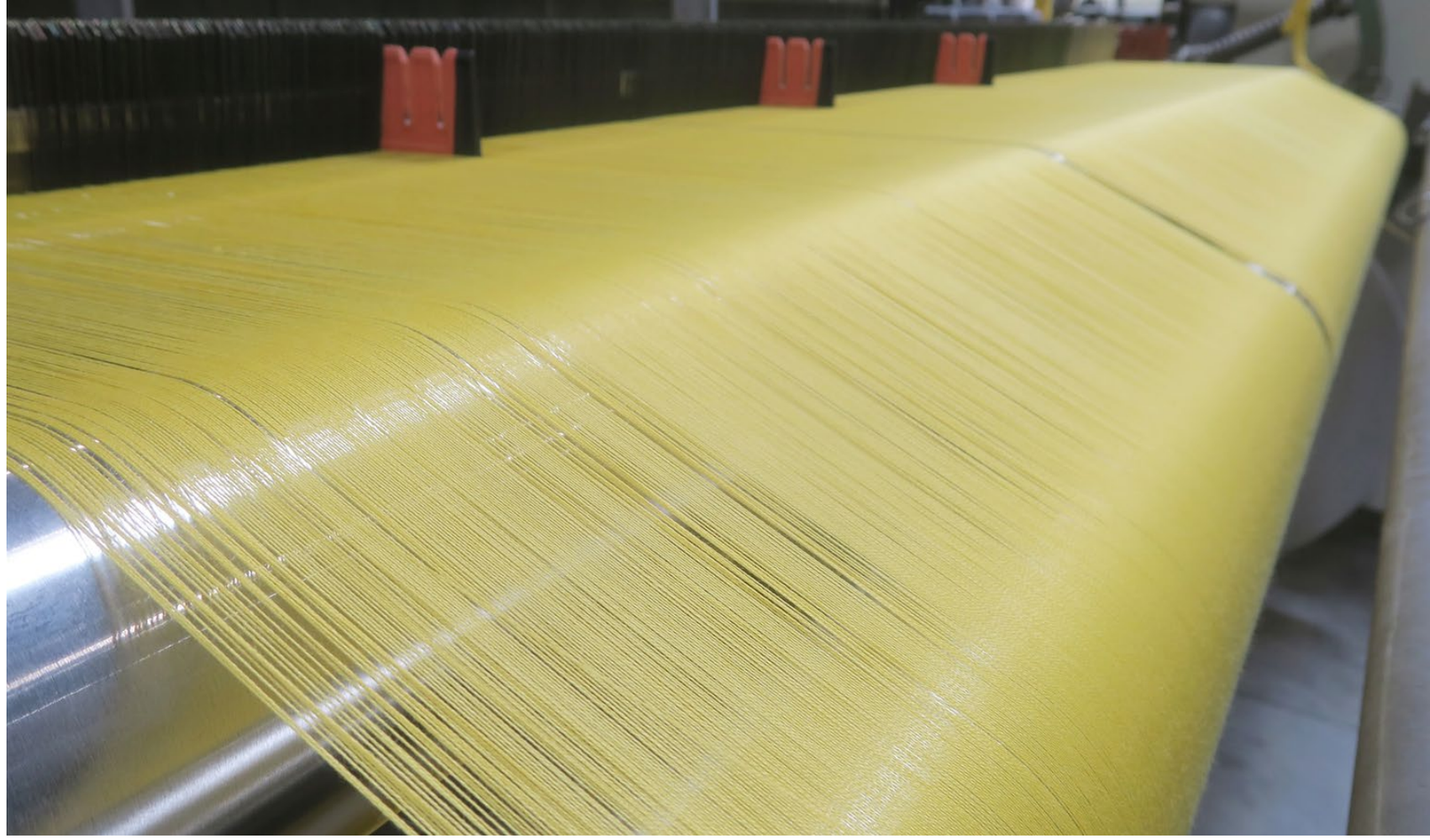
SusTexEdu project (Education Partnership of Textile and Clothing Sector Materials & Sustainability, Agreement number 2021-1-FI01-KA220-HED-000023002) was funded by the Erasmus+ programme of the European Union.

Visit the project website to see all the intellectual outputs of the project.



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