CLEANTEX

Clean and Innovative Textiles Strategy for Circular Economy

MODULE 4
Waste Management and Recycling

Unit 4.2
Textile and Clothing Waste

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In unit 4.2 the definition of textile waste and the classification into different types based on their source of generation, toxicity disposal and discarding are presented, with a focus on pre and post consumers, toxic and industrial waste are presented.
Furthermore, an overview on wastewater and air pollution deriving from textile industry is provided.
Finally different sorting technologies are discussed.

We can affirm that waste consists of substance that reaches at the end of its life span for a person or business, which is normally disposed of, in addition to other wastes, at a landfill, and that, in turn, creates difficulties for the environment and different sectors of society. Different types of waste can be classified as solids, liquids, or gases, according to their physical state. Different types of solid waste can be classified according to their original use (packaging waste, textile waste, food waste, etc.), materials (glass, paper, etc.), physical properties (combustible, compostable, recyclable, etc.), origin (domestic, commercial, agricultural, industrial, etc.), and safety level (hazardous or nonhazardous). Household waste and commercial waste together can be classified as municipal solid waste The world's annual waste generation amounts to 7–10 billion tonnes in total, approximately 2 billion tonnes of which is municipal solid waste.
The European Union's Waste Framework Directive (WFD) - the umbrella Directive that provides definitions for many legislative documents concerning packaging waste, end-of-life vehicles (ELV), or waste from electronic and electrical appliances, to name a few -defines 'waste' as:
Art. 3(1): 'Waste' means any substance or object which the holder discards or intends or is required to discard.
This definition, and the general approach in the EU legal framework, does not make a distinction whether waste is used for other purposes (i.e., re-use, recycle, other recovery, e.g., energy recovery) or disposed of.

Regarding textile waste it can be defined as the textile by-product of the manufacturing of garments, fabrics, yarns or fibres that are deemed unusable for its original purpose by the owner.
It can include fashion and textile industry waste, created during fibre, textile and clothing production, and consumer waste, created during consumer use and disposal.
World textile production has been consistently increasing in recent years. Global population growth and rising living standards have caused an increase in textile demands as a natural consequence of basic needs and have also resulted in overconsumption as a consequence of fast fashion trends. According to forecasts, the world's population will reach 8.2 billion in 2025, with a current annual growth rate of 1. A World Bank study has predicted a 70% global increase in municipal solid waste by 2025, which means that the estimated waste volume will rise from today's 1.3 billion tonnes per year to 2.2 billion tonnes per year by 2025.
For example in Europe, only around 2.8 mln tons of textile were collected in Europe, whereas more than 4 mln tons have largely disappeared in incinerators or landfill alongside with residual waste.

Textile and fashion waste can be classified into different types based on their source of generation, toxicity, disposal and discarding:

- Pre consumer and post consumer wastes
- Solid and soft waste
- Industrial textile waste
- Toxic waste

Pre consumer textile waste, according to Council for Textile Recycling, is the waste generated during production— by processing fibers, and the production of finished yarns and textiles, technical textiles, nonwoven, garments and footwear, including offcuts, selvages, shearings, rejected materials and/or B-grade garments. It's generated in the textile supply chain prior to reaching the consumers.

We can say that pre consumer material originates from the production of a product, post-consumer material originates from its use.

Infact the post consumer waste in textile is the waste generated at various levels after usage of the finished product by end consumer and could be any clothing or household article which has been discarded or not in use for any reason like being worn out, damaged or outgrown.

Waste can come from different mechanical processes in textile manufacturing like:

- spinning
- weaving
- knitting
- garments manufacturing

Spinning

It's a procedure of producing/converting fiber materials in yarns.
The fibres generated by the spinning industry have various other materials like seeds, twigs, dead insects and dust. At each stage of spinning, there are different types of wastes like blow room waste, carding waste, dropping, sliver waste, draw frame waste, ring frame waste pinning.

Weaving

It's the second level after spinning. In this process the yarn from spinning section is sent further for doubling and twisting.
Different types of wastages are:
Residual yarns left on the scones after warping: in the warping creel section, it is not possible to empty all the cones and there will always be a little amount of yarn left on the cones.
Sizing waste: another kind of waste in a weaving factory, when in the weaver's beam section a new set of warp yarn is started then it is necessary to eliminate some portions of the yarns to ensure that properly sized yarns are wounded on the weaver's beam
Knotting waste: knotting is done to ensure all the warp ends of two beams are available for attaching together
Beam residual wastage: when a weaver beam is finished, a small amount of warp yarn remains unused on the weaver's beam and it is not possible to finish yet
Auxiliary selvedge wastage: is a fake selvedge used to hold the weft yarn during the loom beat up period.

Knitting

It is a method by which a yarn or thread is converted into cloth or fabric or any other form.
Wastage may occur due to any reason like yarn, fabric faults, lack of machine maintenance, sample production, problem of management, etc.
There are various types of knitted fabric faults like barriness, spirality, thick and thin place, holes, slubs, sinker marks, stains, stripes etc.
Barriness are horizontal stripes or streaks of uniform or uneven width, visible in the fabric. It occurs when the yarn is at high tension or there is a high level of variation in the thread count in the fabric.

Garment manufacturing process

It is the end procedure converting semi-finished cloth into finished cloth.
Wastage can occur at various stages:

- Inspection: sample from technological test
- Cutting room: wastage can be occurred from several sources, such as marker utilization, cutting waste, roll surplus etc.
- Sewing room: Fabric strips from overlock machines, thread remains, elastic tapes ends
- Final inspection: waste due to finishing/Ironing problems, measurement faults, size mistakes etc.

Another classification of waste in production is soft and hard waste:
Soft waste is the waste in which fibers are relatively open structure and can be reused at an earlier feed stage, it's generated from bloom to the ring frame and is reusable for producing a low quality of yarn;
Hard waste is the waste in which fibers are packed in a closed structure and need additional operations before reusing them with soft waste. These wastes are produced in ring frame, winding, weaving preparatory and during weaving operations.

The majority of solid waste originates from other sources during operations like transportation, bale openings, servicing process and housekeeping. The waste under this category includes:

- Tubes, pallets, cones, containers, drums
- Plastic wrap, corrugated cardboard
- Seam waste, paper waste
- Bags, shipping cartons

Textile packaging contributes a significant amount of solid waste that damages the environment. The industry has responded in different ways to reduce the waste generation by promoting recycling, reuse, energy recovery, minimization, and using novel compostable polymers. This management of packaging waste is being adopted by large retailers and brands in their effort to promote sustainability.

Textile waste can be classified based on their toxicity:
Hard to treat Wastes
Hazardous or toxic wastes
Dispersible waste
High volume wastes

Each of having characteristic that demand different pollution prevention and treatment approach.
Hard to treat Wastes: this category includes those that are persistent, resist treatment, or interfere with the operation of waste treatment facilities. These include colour, metals, phenols, certain surfactants, toxic organic compounds, pesticides, as well as phosphates.
Hazardous waste, a subgroup of hard to treat wastes: The impact on the environment of such kind of wastes is significant. They include metal, chlorinated solvents, non-degradable surfactants and other non-biodegradable or volatile organic materials. These wastes originate often from non-process operations, such as machine cleaning
Dispersible waste: prominent source of dispersible wastes in textile wet processing are the following: Print paste, lint, coating operation, solvent, waste stream from continuous dyeing, printing, finishing etc.
High volume waste: High volume wastes are sometimes a problem for the textile processing units. These include water from preparation and dyeing stages, alkaline wastes from preparation, salt, cutting room waste, knitting oils and warp sizes. These wastes sometimes can be reduced by recycle or reuse as well as by process and equipment modifications.

Wastewater

The textile industry is water-consumption intensive. Specifically, it is estimated that approximately 93 trillion liters of water is consumed yearly for the needs of the global textile industry. During manufacture, wet process as desizing, scouring, bleaching dyeing, printing, and finishing uses a considerable quantity of potable water and releases highly contaminated wastewater (high concentration of dyes and metals).

Untreated effluents which are directly discharged into water sources contaminate water streams and cause environmental problems and health issues for humans.

The main environment parameters used to establish the wastewater pollutants are: Ph, Temperature, Chemical oxygen demand (COD), Biological oxygen demand (BOD), Total suspended solids (TSS) and Total Dissolved solids (TSS), but also colour and toxicity.

Her some definitions:

- COD (Chemical oxygen demand): the overall oxygen concentration required for to chemical oxidation of all the organic compounds contained in a wastewater sample.
- BOD (biological oxygen demand): the concentration of oxygen consumed during the degradation of organic compounds contained in a wastewater sample; BOD is based on the principle that if sufficient oxygen is available, aerobic biological decomposition (i.e., stabilization of organic waste) by microorganisms will continue until all waste is consumed.
- TSS and TDS measure the amount of particulate matter (tiny pieces of things) floating in water. The particles that are large enough to be held back by the filter are called total suspended solids (TSS), while the particles that pass through the filter are called total dissolved solids (TDS).
- Toxicity: measurement of inhibition biological processes caused by some substances present in water on the metabolism of the organisms.

An overview on the textile Wastewater treatments is provided in Module 6 unit 1.

Air pollution is the introduction of chemicals, particulate or biological material that cause harm or discomfort to humans or other living organisms, or damages the natural environment into the atmosphere.

All textile-manufacturing processes generate environmental pollution.: workers are exposed to the risk of breathing air polluted with dust and fly and contracting respiratory ailments, byssinosis (lung disease), chronic bronchitis etc.

Air pollutants produced by the textile industry include:

• nitrous oxides and sulphur dioxide produced in the energy production stages;

• volatile organic components (VOCs) produced in coating, curing, drying, waste water treatment and chemical storage;

• aniline vapours, carrier Hydrogen sulphide, chlorine and chlorine dioxide produced in dyeing and bleaching stages.

Some steps to reduce emission to air include:

- Decreasing emissions of organic solvents by changing to water-based products
- Using scrubbers to collect particulate matter
- Optimization of boiler operations to reduce the emissions of nitrous and sulphur oxides
- Pre-screening chemicals using the material safety data sheets to ensure that chemicals are not toxic
- Identifying sources of air pollution and quantifying emissions.

Collecting and sorting

The collection rates of textile waste in the EU are roughly 25%, with differences across Member States. A revision of the EU Waste Framework Directive (Directive 2008/98/EC) will oblige Member States to collect these discarded textiles separately by January 2025, but handling the immense volumes of used clothing poses a challenge.
In Europe each country has different success-levels of collection of end-of-life textiles and their further treatment. Collection rates and the type of schemes to collect used textiles, vary significantly, both nationally and regionally. Collected amounts of used textiles vary greatly across countries (between 0.3 and 15.3 kg/person).

Sorting is the process that immediately follows the separate collection of used textiles and textile waste.
In the sorting facilities, used textiles are sorted to determine their further fate: reuse (and for which market), recycling (and which type of recycling) or landfill/Incineration.
The sorting process can potentially be an important component of economic and environmental costs of the recycling process, as the better the textiles are sorted into pure fractions (e.g. 100 % cotton), the bigger the chance of selling the textiles to a recycling facility where it can be recycled.

There are three type of sorting:
- Manual sorting (including specialised manual sorting)
- Manual sorting with sophisticated aiding techniques
- Automated sorting

Manual sorting is not a technology as such, as it is performed by humans and usually done without technological aids apart from conveyor belts and other feeding technologies. It's the most widespread textile sorting approach used in Europe with hundreds of sorting facilities sorting hundreds of thousands of tonnes of used textiles. In France alone, for example, there were 54 sorting centres operating in 2018, sorting just under 160 000 tonnes of use textiles.
Manual sorting required experienced staff, so it's relatively expensive, furthermore it is difficult to determine detailed fibre compositions by hand – only rough sorting by fibre-type is possible.
Following receipt of used textiles at a sorting centre, all non-textile waste is removed as the first part of the manual sorting process: at this phase batches of textiles that are contaminated by rainwater, mould, oil etc. are also removed., this step cab be carried out by less skilled personnel.
The next phase is to remove non-reusable clothing and textiles (non-reusable textiles can be identified through damage such as rips and tears, miscolouring, missing components etc.).
The reusable fraction is then passed on (typically via conveyor belts) to the most skilled sorting personnel to sort these into different categories, using their sight and sense of touch. The number and type of categories the reusable textiles are sorted into depends on the facility and on the demand.

Manual sorting with sophisticated aiding techniques is also often referred to as semi-automated sorting.
We refer to technological aids for assisting in the actual sorting of fibre types and grades for reuse and recycling, for examples held scanners that can be used by the manual sorters to assist them in determining material content.
Advantages are:
- the sorting for high-quality recycling can theoretically be carried out at the same time as sorting for reuse rather than requiring a new facility and processing stage. This can reduce space needs and costs
- Cost of machinery lower than the cost of labour.

Example of manual sorting with sophisticated aiding technique is the Swiss company TexAid that collects, sorts and recycles used textiles. Since 2008 the sorting personnel at the TexAid sorting plant in Schattdorf in Switzerland have been using a headset that help them classify every single textile by material, quality and texture using their voice. This voice-controlled sorting system is linked up to a computer that ensures that each piece of textile, via a belt and air blowers, finds its way to the correct storage container. This is done via an air blast that sends the textiles to a stillage or a large bag. The voice-operated pre-sorting system has been integrated to facilitate the sorting of textiles into 60 categories.

Automated sorting can efficiently and accurately sort most textile wastes by colour and fibre type ready for input into high-quality mechanical or chemical recycling. Among the most promising technologies are near-infrared spectroscopy (NIR) as used by Fibersort in the Netherlands and radio frequency identification (RFID) as used by Tex.IT in Sweden.

Near-infrared spectroscopy (NIR) is a technique sensitive to the molecular absorptions of organic constituents in the near infrared part of the spectrum, so types of fabric that can be recognized and sorted into uniform categories of fibers with specified compositions, colors and/or structures.
Fibersort is a European Interreg funded project (Interreg North-West Europe Fibersort, 2021) where during a 3-and-a-half-year period a demo plant for automated textile sorting using near-infrared spectroscopy was built and operated outside of Amsterdam.
The system allows the detection of garments from cotton, wool, viscose, polyester, acrylic and nylon.
The sorted fibres have a low level of contamination and can serve as mono-fibre inputs in mechanical as well as chemical recycling for high value textile-to-textile recyclers.
Radio frequency identification (RFID) is a method based on radio-labels enabling information to be stored and recovered remotely.
RFID labels are implanted into the product. They generally contain an identifier which allows a certain amount of information on the product to be found thanks to an external data base (serial number, manufacturing date).
Tex.IT is a Swedish project that implements the use of digital information carriers (RFID tags) integrated in garments to increase future traceability throughout the supply chain and facilitate subsequent sorting processes prior to recycling.

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