TEXTILE MANUFACTURING: CAN WE MEASURE SUSTAINABILITY?

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Prof. F. Javier Sardina
University of Santiago de Compostela
SPAIN
SUSTAINABLE FASHION?

Fashion (and textile manufacturing) sustainability is one of the most difficult conundrums that the Industry faces today, but it is probably the most important to solve because it will dominate the conversation for years to come.

What is sustainable fashion?

Sustainable Textiles?

With regards to the sustainability of textile articles there are many stakeholders involved, with many different opinions, asking many questions, for which we have very few significant answers:

1. What fibers make up this fabric? i.e. synthetic or natural, plant or animal
2. What makes this fabrics ethical? i.e. organic, low water usage, highly renewable, etc.
3. Where do these fabrics come from? Determining geographic location helps you access the way workers are treated as well as the environmental impact of shipping the goods
4. Are sustainable practices used in the cultivation of crops? i.e. wastewater recycling, crop rotation
5. Is the fabric recycled?
6. Can the fabric be recycled?
Sustainability involves a complex mix of environmental, social, psychological and industrial aspects.

**Sustainable fashion**, also called **eco fashion**, is a part of the growing design philosophy and trend of sustainability, the goal of which is to create a system which can be environment friendly and social responsible.

- **SLOW FASHION**
- **MATERIAL INNOVATION**
- **RE-USE**
- **REDUCE**
- **RE-CYCLE**

DON’T LET FASHION GO TO WASTE.
WHO MADE MY CLOTHES?
BE CURIOUS
FIND OUT
DO SOMETHING
CLOSING AND SLOWING THE LOOP. Innovative business models in the textile sector – an overview (July 2016)

It is increasingly acknowledged, even by industry, that fashion needs to apply ecological thinking to develop innovative ideas for evolving its practice beyond the growth and consumption model that dominates fashion today. The reality of planetary boundaries sets limits on production and consumption. It also obliges the industry to experiment and look into alternatives to the “make-buy-use-dispose” model.

A NEW TEXTILES ECONOMY: REDESIGNING FASHION’S FUTURE (November 2017)

The time has come to transition to a textile system that delivers better economic, societal, and environmental outcomes. The report “A new textiles economy: Redesigning fashion’s future” outlines a vision and sets out ambitions and actions – based on the principles of a circular economy – to design out negative impacts and capture a USD 500 billion economic opportunity by truly transforming the way clothes are designed, sold, and used.
SUSTAINABILITY: DEFINITIONS

SUSTAINABILITY is a password to access a world of opportunities (competitive advantages) in the fashion industry, for manufacturers as well as for retailers. But we have not yet agreed on a complete definition. Here I present two partial definitions that I particularly like:

One definition focuses on not abusing the World’s resources while manufacturing your articles.

**FOCUS: USE OF RESOURCES**

The other focuses on the effects of manufacturing practices on the environment and on the efficiency of the whole process.

**FOCUS: OPTIMIZATION AND ENVIRONMENTAL IMPACT**

But, beyond definitions, can we MEASURE how sustainable our materials, processes and articles are? Because if we cannot, then there is very little that we can do to make the fashion industry (more) sustainable.
THE FASHION INDUSTRY: SOME (staggering) NUMBERS

The impacts of the fashion industry (good and bad) are huge

- **$2.5 trillion industry**
- **1 in 6 people in the world work in fashion & related industries**
- **2nd highest user of water**
- **2nd highest polluter** Responsible for 10% of global carbon emissions
- **80%**
- **85% of textiles are sent to landfills**
- An estimated **21B tons per year**
SUSTAINABILITY IN THE FASHION INDUSTRY: THE SITUATION

Besides water usage and pollution, if we look at the big picture of how we use our materials, the situation is not rosy at all.

tiny.cc/fibres
SUSTAINABILITY IN THE TEXTILE MILLS: THE SITUATION

Let’s check some numbers on other two important issues: energy and chemicals consumption

Energy, water and chemical consumption values of t-shirt production in Turkey (2015)

<table>
<thead>
<tr>
<th>PROCESS</th>
<th>SUBPROCESS</th>
<th>CHEMICALS CONSUMPTION</th>
<th>%</th>
<th>ENERGY CONSUMPTION</th>
<th>%</th>
<th>WATER CONSUMPTION</th>
<th>%</th>
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<tr>
<td>PREPARATION</td>
<td>BLEACHING</td>
<td>0.118</td>
<td>10.6</td>
<td>8.34</td>
<td>33.1</td>
<td>50</td>
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<td>COLORATION</td>
<td>DYEING</td>
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<td>85.7</td>
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<td></td>
<td>DRYING</td>
<td></td>
<td></td>
<td>1.80</td>
<td>7.1</td>
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<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>1.108</td>
<td>25.2</td>
<td>25.20</td>
<td></td>
<td>150</td>
<td></td>
</tr>
</tbody>
</table>

(Kg/Kg of textile) (MJ/Kg of textile) (L/Kg of textile)

Source: C. Baydar, N. Ciliz, A. Mammadov. Resources Conservation and Recycling, 2015, 104, 213-233 (Bogazici University, Istanbul)

So, if you own a textile mill, the picture of your sustainability issues looks a little like this:
SUSTAINABILITY IN THE TEXTILE MILLS: THE SITUATION

Is that all that we need to take into account? The answer is NO. We need to go into far greater detail in some issues. For instance, regarding chemicals usage we are not just concerned about the amounts of them that we use in the whole lifecycle of the articles, we are also deeply worried about their levels of hazardousness.

So, your idealized textile mill picture becomes a little more complicated:
Thus, sustainability is a very complex issue but, why should we bother measuring it (if that is at all possible!)

“Measurement is the first step that leads to control and eventually to improvement. If you can’t measure something, you can’t understand it. If you can’t understand it, you can’t control it. If you can’t control it, you can’t improve it.”

H. James Harrington
Tools for comparing the sustainability levels of materials have become commonplace in the last few years. Such are classifications of fabrics, for instance. The following list is just one example:

**Environmental impact textile fibres**

- **Classification by Made By**
  - **Class A**
    - Recycled cotton, recycled nylon, recycled polyester, organic hemp, organic flax (linen)
  - **Class B**
    - Tencel, organic cotton, in conversion cotton
  - **Class C**
    - Conventional hemp, Ramee, Pla, Conventional flax (linen)
  - **Class D**
    - Virgin Polyester, poly-acrylic, Lenzing Modal
  - **Class E**
    - Conventional cotton, virgin nylon, rayon (cuproammonium), Bamboo-viscose, wool, generic viscose
  - **Unclassified**
    - Silk, organic wool, leather, elasthan, acetate, cashmere, alpaca
HOW DO WE MEASURE SUSTAINABILITY?

- But, are some listings of materials enough to understand sustainability? The answer is NO, because the approach itself (the classification of materials) has low practical relevance: (1) we cannot substitute cotton for polyester so it is rather useless to know which one is “more sustainable”, and (2) we cannot compare the same material from different manufacturers.
- It is more interesting to understand how to improve the sustainability of one specific material, to compare materials from different manufacturers or to compare two materials that can really be substitutes for each other.
- As an exercise, let’s study the sustainability of viscose, tencel and polyester and analyze all the relevant factors. Our approach is to divide the entire manufacturing process/material/article into homogeneous sub-processes which can be analyzed independently.

Our strategy:

- The material/process/article is disaggregated into sub-processes which are analysed separately.
- Only the steps more relevant for sustainability are taken into account for the evaluation.
- Indicators are sought and classified according to their influence on sustainability.
- Key indicators (the ones that influence sustainability most) are established.
- Sustainability indexes are determined. Vectors of improvement can be selected.
SUSTAINABILITY CASE STUDY: POLYESTER

Crude oil → Raw materials → Polymerisation → Fibre production → Polyester fibre

QUANTIFICATION OF SUSTAINABILITY

- Social Impact
- Logistics Involved
- Manufacturing Process
- Hazards
  - Water
  - Energy
  - Residues
  - Materials
Viscose is obtained from the cellulose contained in wood. Wood is composed of approx. 50% cellulose and 50% lignin. Cellulose is separated from lignin through a complex chemical process.

Sustainable forests ➔ Wood ➔ Pulp factory ➔ Dissolving wood pulp ➔ Fiber production ➔ Viscose/Tencel

**Wood**
- Issues:
  - Deforestation
  - Global Warming Potential

**Dissolving Pulp Production**
- Issues:
  - Raw materials consumption
  - Energy Balance
  - Bleaching chemicals

**Effluents & Emissions**
- Issues:
  - Wastewater
  - Air emissions
  - Solid wastes

**Manufacturing (Chemical) Process**
- Issues:
  - Raw materials consumption
  - Energy used
  - Water used

Four areas for evaluating the sustainability and environmental impact of viscose production
SUSTAINABILITY CASE STUDY: VISCOSITY/TENCEL

Dissolving Pulp Production

- Raw materials
- Energy
- Water
- Bleaching agents

Inputs

- Wood
- Chipper bin
- Impregnation
- Digestion
- Washing
- Bleaching
- Manufacturing process

Outputs

- Spent Liquor
- Wastewater

Dissolving Pulp

Focus:
- Amount of raw materials used
- Energy balance
- Volume of water used
- Amount of waste produced
SUSTAINABILITY CASE STUDY: VISCOSE/TENCEL

Dissolving Pulp Production: KEY SUSTAINABILITY INDICATORS

Key indicators:
- Total reduced sulphur (TRS) reduction in recovery boilers
- Air emission treatment

Key indicators:
- Energy obtained
- By-products produced

Key indicators:
- COD and BOD reducing treatment
- Chlorine removal
- Water recirculation

Wood → Dissolving pulp → Wastewater treatment → Wastewater

Air emission → Air treatment → Energy

Chemicals

Water

Solids → Solid waste

Spent liquors → Liquor treatment

By-products

Acetic Acid
Furfural
Xylose
Sodium Carbonate
Magnesium lignosulphonate

Valorization of solid wastes
SUSTAINABILITY CASE STUDY: VISCOSE

Fiber production (chemical process)

- Sodium hydroxide
- Carbon disulphide
- Sulphuric acid
- Zinc sulphate
- Bleaching agents

Manufacturing process:
- Dissolving Pulp
- Stepping
- Xanthation
- Spinning
- Washing

Outputs:
- Viscose
- Wastewater

Focus:
- Amount of raw materials used
- Amount of energy used
- Amount of water used
- Amount of waste
Fiber production (chemical reaction): KEY SUSTAINABILITY INDICATORS

Key indicators:
- % Sodium hydroxide recovered
- % Carbon disulphide recovered
- % Sulphuric acid recovered and generated
- % Zinc sulphate recovered
- Amount of sodium sulphate produced
SUSTAINABILITY CASE STUDY: VISCOSE vs. LYOCELL

Fiber production (solution process)

- Dissolving Pulp
- Solution making
- Evaporation
- Spinning
- After-treatment
- Lyocell

Inputs:
- NMNO
- Propyl Gallate
- Sodium hydroxide
- Energy
- Water

Outputs:
- Wastewater

Focus:
- Amount of raw materials used
- Amount of energy used
- Amount of water used
- Amount of waste
Fiber production (solution process): KEY SUSTAINABILITY INDICATORS

- % N-methyl morpholine oxide recovered
- % Water recovered
- Amount of additives added
Polyester is obtained from crude oil. Crude oil is processed to obtain the correspond monomers which are polymerised to obtain polyester chips. These are employed to produce the polyester fibre through a spinning process.

The four areas for evaluating the sustainability and environmental impact of polyester production.
Crude oil is processed by steam cracking, obtaining different fractions which experience further separations. Two fractions are important for PET production:

1. **Naphtha**: From this fraction is obtained xylene. From xylene two substances can be obtained: TPA and DMT
2. **Ethylene**: Ethylene fraction is oxidised to afford ethylene oxide, which is further converted into ethylene glycol.

**PET production**: Two processes are available:

1. **DMT method**: DMT is polymerized with ethylene glycol in presence of metal catalyst at 265-285 °C to afford the PET polymer.
2. **TPA method**: The TPA is polymerized with ethylene glycol in presence of metal catalyst at 250-290 °C to obtain the PET polymer.

**Focus**:
- Amount of raw materials used
- Amount of energy used
- Amount of waste
The polyester spinning process usually has the following characteristics:

- Temperatures about 300°C are commonly required.
- Mechanical energy and pressure is required for extrusion and spinning process.
- Molten polymer is forced through the spinneret.
- Filaments are cooled by air in the blowing tunnel.
- The drawing step change the PET state from amorphous to oriented crystallites.

All these processes are highly energy demanding.

**Focus:**
- Amount of raw materials used
- Amount of energy used
- Amount of waste
Outputs:

- A database with the most relevant sustainability information on the relevant sub-processes used for manufacturing the material/process/article.
- The data can be adequately analysed and transferred between analogous sub-processes.
- Key indicators allow the quantification of the sustainability and the optimization of resources (time, personnel, knowledge).
- Key indicators allow the identification of the most problematic steps/sub-processes (for priority intervention).

Other applications of our methodology (in progress):

- Products: cosmetics
- Processes: textile dyeing