Sustainability challenges of the textile industry and opportunities for innovation

Dr. Richard Blackburn

@RichardBlackb18
Necessity for Sustainable Products

- 2012 - world population 7 billion
- 2050 - expected to rise to over 9 billion
- Increases demand
  - food, energy, water, resources, chemicals
- Increases environmental burden
  - pollution
  - depletion of finite non-renewable resources (e.g. fossil fuels)

- Synthetic chemical products and processes afford a significant improvement in quality of life
- Growing middle class want these consumer products too
Synthetic fibre revolution

- 20th Century polymers
  - nylon, 1935
  - polyurethane, 1937
  - polyester
    - Terylene, 1941
    - Dacron, 1946
  - acrylic, 1944
  - polypropylene and HDPE, 1951
Synthetic fibre sustainability challenges

- Non-degradable, non-renewable
- Increases oil consumption
- Contribution to anthropogenic GHGs
- **Significant oil supply issues**
- **But**, polyester highest share of textile market (>50m tpa)
- Raw materials for fibres has to change
- Recyclable – mechanical or chemical?
Definition of Sustainability

- Environment
- Economy
- Society
Sustainability considerations

- RAW MATERIALS
- ENERGY
- WATER
- EMISSIONS
Public perception

Sustainable?

Is it green?? Is it ethical??

Do I care about green issues??

What influence does media have on public opinion?
Public perception

- Demand (and rejection) for consumer products can be driven by the public and the media
- "Biodegradable", "Natural", "Organic"
  - perceived by the public to be good for the environment
- "Synthetic", "Non-organic", "GM"
  - perceived by the public to be bad for the environment
- "Chemistry"
  - Public perception of science…
- Do the public understand what "Sustainable" means?
Definition of Sustainability

• Most important concept is ‘sustainability’

• Sustainable living is taking no more potentially renewable resources from the natural world than can be replenished naturally

• To not overload the capacity of the environment to cleanse and renew itself by natural processes

• Resources are sustainable if they cannot be used up
Sustainable Life Cycle

Idealised life cycle of sustainable products

- Product
  - Production
    - Harvest
    - Extracting renewable sources (starch, cellulose, etc.)
  - Processing

- Primary use
  - Combustible waste
  - Biodegradable waste

- Re-use/recycling
  - Incineration
    - CO₂, H₂O
    - Energy
  - Composting
    - CO₂, H₂O
    - Photo-synthesis

Plants

- Photo-synthesis
Polymers in the environment

- Volume in waste disposal and landfill is very high
- Polymers do not degrade very readily
- Not just synthetic polymers!
- Landfills are decreasing in number

Is this changing?
Recycling of polymers is on the increase and should be encouraged. Consume a significant amount of energy & too many different polymers. Necessity for biodegradable polymers.
Disposal of biodegradable polymers

- Carried out by the public through a composting mechanism
- System requires infrastructure
- Collection systems and composting facilities
- Germany has invested in compost infrastructure
- More than 60% of all German households issued organic waste bins
It is important to consider the whole life of a product to assess its environmental impact – life cycle analysis.
Ideal sustainable products

- Provide an **equivalent function** to the product it replaces
- **Performs as well as or better** than the existing product
- Be available at a **competitive or lower price**
- Have a minimum environmental footprint for **all the processes involved**
- Be manufactured from **renewable resources**
- Use only **ingredients that are safe** to both humans and the environment
- **No negative impact** on food supply or water
Green Chemistry Is About...

- Reducing
- Waste
- Materials
- Hazard
- Risk
- Energy
- Environmental impact
- Cost
Where does the waste come from?

Areas traditionally thought of as being dirty (oil refining & bulk chemical production) are relatively clean - they need to be since margins per kg are low.

Newer industries with higher profit margins and employing more complex chemistry produce much more waste relatively.
CASE STUDY: Problems with cotton

- **NATURAL doesn’t necessarily mean sustainable**
- Cotton production >25 million tpa
- High levels of pesticides (25% world total) and insecticides (11% world total)
- Very high irrigation levels
  - 1 kg of cotton fibre requires 20,000-40,000 L (water you consume in a lifetime)
- Only grows in certain climates
  - Deforestation to grow cotton
- High area of land for mass of useable fibre
- Organic cotton not a viable alternative on a global scale
Sustainable cotton?

Organic cotton

- Widely promoted as the answer to cotton’s problems
- Global production (in over 20 countries, mainly India) only 1.1% of world cotton production (Textile Exchange)
- Must wait 3 years for land to be ‘organic’
- Only genetically unmodified seed
- No herbicides or pesticides
- Ethical labour employment standards
- Requires approximately 1.4x area of land to produce same mass of fibre
- Still has very high water consumption
- Not a viable alternative on a global scale to completely replace non-organic cotton
Sustainable cotton?

Organic cotton challenges
- Limited organic insecticides
- Lower yields, crop dependent
- Yields more variable
- Higher water usage
- Labour availability
- Higher labour cost for hand weeding

Organic cotton certification
- Not based on a test
- Production practices must be documented
- Process described in Organic Systems Plan
Sustainable cotton?

Better cotton

- GM pest-resistant strain referred to as ‘Bt cotton’
  - Naturally occurring protein (used by organic gardeners) – kills bollworm pests (moth larva)
  - Reduces pesticide sprays from 5 sprays to 0
  - Poisoning of workers virtually eliminated
  - may reduce presence of bollworm on other host crops and may decrease the need for insecticide sprays in general
  - More productive, particularly in India, Bt cotton is regarded as less ‘natural’
  - Cannot be classed as ‘organic’

- Better Cotton Initiative (BCI) set up to foster improvements in the sustainability of cotton production methods
Fairtrade Cotton

20 MILLION GARMENTS

10,000 farmers in West Africa and India

Guarantees a better deal for Third World Producers
Worlds Largest order for Fairtrade Cotton

Guarantees a better deal for Third World Producers

Greener Living

Think green. Shop smart.
Domestic impact on LCA of cotton

Extracted energy consumption

Major Sustainable Fibre Types

- Bast Fibres
  - flax, hemp, jute, ramie, kenaf and abaca
- Regenerated cellulosics
  - Lyocell (Tencel), modal
- Poly(lactic acid) (ingeo)
- Wool
Lyocell & Modal – Highly efficient use of the raw materials

- Lenzing manufactures lyocell
- Pulp production at the Lenzing site achieves a wood utilization rate of over 50%
Modal
TENCEL® (lyocell) – the most sustainable fibre production process

- Wood and pulp from certified forests
- Direct dissolution process
- N-methylmorpholine-N-oxide (NMMO)
- Closed-loop process
- >99% recovery of solvent
Lyocell & Modal – Comparison of energy sources

<table>
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<tr>
<th>Energy Source</th>
<th>World 2010</th>
<th>Lenzing Group 2012</th>
<th>Lenzing Site 2012</th>
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<tr>
<td>Biogenic</td>
<td>13.2%</td>
<td>50.3%</td>
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<td>Oil</td>
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<tr>
<td>Gas</td>
<td>21.5%</td>
<td>16.0%</td>
<td>5.5%</td>
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<tr>
<td>Coal</td>
<td>27.3%</td>
<td>33.1%</td>
<td>5.6%</td>
</tr>
</tbody>
</table>

*) incl. RVL
Sources: World Energy Outlook 2012, Lenzing AG
Green footprint: significantly more environmentally than cotton

- More than 50% of Lenzing’s fuel consumption sourced from renewable resource
Textile dyeing processes

- Traditional dyeing processes use 5.8 trillion litres water p.a.
  - ~3.7 billion Olympic swimming pools
- 10-20% dye remains after dyeing (plus other chemicals), leaving potential for wastewater pollution
  - One fifth of the world's industrial water pollution (World Bank)
- 391 billion kWh energy for dyeing processes
- Innovative technologies needed to reduce, or eliminate, water, energy and auxiliary chemicals in dyeing
Polyester dyeing process

- Hydrophobic fibre dyed with hydrophobic disperse dye
- Traditional aqueous process requires dispersing agents/surfactants and high temperatures (typically 130 °C) under pressure
- Other dyeing auxiliaries often required
- Large amount of waste dye left over in effluent
- Surface dye removed with surfactants and/or reducing agents
- Innovation in scCO$_2$ dyeing to completely change polyester dyeing process
Abel Kirui wins silver in London 2012 Marathon singlet in dyed using DyeCoo process
• System comparison with traditional polyester dyeing

**WATER**
Zero water used

**WASTEWATER**
Nearly 100% dye used in process.
Zero waste

**ENERGY**
Reduces energy consumption by 63%

**PROCESS CHEMICALS**
No auxiliary chemicals required

**FOOTPRINT**
¼ of physical footprint to dye same amount of fabric

**EFFICIENCY**
40% faster than traditional dyeing processes
Coloration of cotton

- Dyeing of cotton primarily conducted using reactive dyes
- Despite development of dyes with high fixation, dyeing process has many problems:
  - SALT
  - COLOUR IN EFFLUENT
  - WATER
- Pre-treatment of cotton demonstrated 10-15 years ago by several research groups
- Water remains a significant problem with the vast majority used in washing processes after dyeing
- Big opportunity for dyeing systems that do not need any washing after dyeing
- Is water in the dyeing process cotton’s biggest problem?
Does fibre coloration have to be through dyeing?

- **Dope-dyeing**: incorporation of colorant into spinning process
- Lyocell process makes this possible for cellulosics

**Diagram:**
- Cellulose pulp
  - Dyeing pulp
  - Mixing dyed pulp with undyed pulp
  - Dissolution in NMMO
  - Fibre spinning and washing
  - Dope-dyed lyocell fibres
**DyeCat Process**

- Catalytic process that allows colour to be integrated directly into polyesters
- Eliminates need for conventional dyeing
- Colour in fibre is generated at the same time the polymer is made
- Colours ‘locked into’ fibre providing a technically superior product
- No need for wasteful dyeing processes

**DyeCat PLA fibre**
  - Renewable
  - Technically superior
  - Saves chemicals and energy
DyeCat Process

- Coloration of polymer during synthesis
- Demonstrated on PLA using coloured catalysts
Best way to mix colours?

- **Nano-level**
  - Mixture of different dyes in dyebath to create desired shade

- **Micro-level**
  - Mixture of different dyed fibres in yarn formation process to create desired shade
  - Mélange Yarn
Fast Fashion

• Consumption of new designs as close as possible to the point of creation
• Fast, low price and disposable
• Business model: reducing time cycles from production to consumption
  • consumers engage in more cycles in any time period
• "Supermarket" market
  • Cost is the consumer's primary buying decision
  • Costs reduced by taking advantage of lower prices in markets in developing countries
  • Developing countries ~75% all clothing exports
• Environmental Impact
  • US imports >1 billion garments annually from China alone
  • UK purchasing of clothing surged by 37% from 2001 to 2005
  • Dramatic increase in environmental damage caused by the textile industry
• An enormous change is needed in the minds and attitudes of consumers
Fast Fashion

- https://www.youtube.com/watch?v=wIVqFyMmmwU
  - Watch from 16:30
Sustainability challenges for the textiles industry

• Greater use of sustainable raw materials
• Lower energy & water consumption and pollution generation in production
• Lower impact in use
  • Water, energy, chemicals in cleaning/laundering
• Design for easy disassembly/disposal/ recycling
  • e.g. how to manage reuse of polycotton?

• DESIGN FOR REDUCED CONSUMPTION AND LONGER LIFE
• ‘Disposable’ products unsustainable
Sustainability challenges for the textiles industry

- Sustainability issues in the textiles industry have often been tackled in industry by tinkering and incremental change.

- Step-change solutions are needed to bring about truly sustainable apparel and footwear products.
Any Questions?

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