Handbook of sustainable textile production

Marion I. Tobler-Rohr
TEXTILE PRODUCTS ARE PRODUCED, DISTRIBUTED, SOLD AND USED WORLDWIDE. A QUANTITATIVE ASSESSMENT OF SUSTAINABILITY IN THE TEXTILE MANUFACTURING CHAIN IS THEREFORE EXTREMELY IMPORTANT. THE HANDBOOK OF SUSTAINABLE TEXTILE PRODUCTION IS A COMPILATION OF TECHNICAL, ECONOMIC AND ENVIRONMENTAL DATA FROM THE VARIOUS PROCESSES IN THIS CHAIN. THIS AUTHORITATIVE REFERENCE WORK PROVIDES A DETAILED STUDY OF THE SUSTAINABLE DEVELOPMENT OF TEXTILES.

THE BOOK OPENS WITH AN INTRODUCTION TO THE TOPIC. CHAPTERS DEFINE THE PRINCIPLES OF SUSTAINABILITY AND ITS USE IN LEGISLATION AND INDUSTRY BEFORE GOING ON TO INVESTIGATE THE IMPACT OF TEXTILES THROUGHOUT THE SUPPLY CHAIN, STARTING WITH THE RAW FIBRE THROUGH TO FABRIC PRODUCTION, CONSUMPTION AND DISPOSAL. TEXTILE PROCESS TECHNOLOGY AND METHODS FOR SPECIFYING QUALITY AND FUNCTIONS IN TEXTILE PRODUCTS IN ORDER TO REDUCE TEXTILE WASTE AND IMPROVE SUSTAINABILITY ARE ALSO EXAMINED. A SERIES OF LIFE CYCLE ASSESSMENTS (LCAS) CARRIED OUT IN THE EUROPEAN TEXTILE INDUSTRY ARE INVESTIGATED. THESE STUDIES COVER A RANGE OF PROCESSES FROM COTTON GROWING, SPINNING AND WEAVING TO THE RECYCLING OF TEXTILES. THE BOOK CONCLUDES WITH A DISCUSSION ON SUSTAINABLE TEXTILES FROM A PRODUCT DEVELOPMENT AND MARKETING PERSPECTIVE.

WITH AN INTERNATIONALLY RECOGNISED EXPERT AUTHOR, THE HANDBOOK OF SUSTAINABLE TEXTILE PRODUCTION WILL BE A VALUABLE REFERENCE TOOL FOR ACADEMICS AND STUDENTS AS WELL AS FOR COMPANIES ACROSS THE TEXTILE SUPPLY CHAIN CONCERNED WITH DEVELOPING A SUSTAINABLE ENVIRONMENT, FROM FIBRE MANUFACTURERS AND DESIGNERS TO REGULATORY BODIES.

Preamble

On the importance of quantitative assessment of sustainability in the textile manufacturing chain

Textile products ranging from the fiber to the garment are made, traded, sold, used and finally discarded worldwide. The technologies, processes, and procedures in use on this life cycle are defined by a few dominating players in business, politics, and technology. Globalized markets have brought a profound change in textile production and sales just recently, and this shift among and concentration on a few major players goes on.

What is the general picture of this global manufacturing network? In the area of raw materials, fibers and polymers, we have government regulation and a few multinational companies setting the rules and the basis for pricing. The same is again valid for the chemical and biological processes in dyeing and finishing, also in genetic technology.

Different to this, textile processing technology and machinery are dominated by small and medium size enterprises. The development of spinning, weaving, knitting, cutting and sewing machinery takes 5 – 10 years from idea to product presentation and requires an investment in the order of hundreds of millions – Dollars or Euros - in research and development. The typical manufacturer of textile machinery is a family owned company, the owners being dedicated to traditional machinery construction, willing to support a crew of engineers eager to excel in making machines with ever growing performance.

It takes generations to accumulate and build up the technical expertise for developing textile machinery. There are only two clusters remaining in the world were this kind of engineering is a core business: North and South of the Alps in Western Europe, and between Osaka and Nagoya in Japan. These two clusters lead in textile manufacturing technology in the same way as Switzerland leads watch making, Italy leads fashion, and Japan consumer electronics.

Moreover, the textile machinery market is extremely competitive on cost and performance. Productivity of the textile manufacturing processes shows an annual growth of 4 % since 200 years, which means that productivity has
always grown faster than consumption. Consequently, the textile industry is globally shrinking, also since 200 years, in spite of the steadily increasing demand of a growing population.

In medieval times, each person had to dedicate more than a quarter of the daily work to cover the personal demand on textiles. Today, the average consumer in an industrialized nation works around 5 minutes per day to cover the cost of the textiles required. In due course, the connection between customer and product has completely changed. The value assigned to a textile product is no longer given by the effort required to make it, but comes from a projection of personal desires and imagination into this product. The symbolic impact of textile goods is perceived far more important than the real value in use. There is no connection anymore between manufacturing cost and retail market pricing. How and by whom the items he or she buys have been manufactured is no longer of any concern.

To sum up: The textile manufacturing chain starts on a raw material basis controlled by agricultural subsidies and trade agreements, goes on through a chain of quick reacting, market driven processes, and ends up at a customer and consumer who is manipulated by the branding of wholesalers and the discounts offered by retailers. This path is not only significant for the economical behavior of the textile markets, but also for the ecological aspect of textile production and consumption. What does this mean for future innovation?

In a mature technology, innovation is directed mainly to reliability and efficiency of the processes. Both of these targets are identical, regarding the performance in economy as well as ecology. The aspect of resources and environmental impact, further treated here with the term sustainability, is increasingly recognized by the customers. However, textiles are purchased with a time horizon measured in weeks and month. But innovative concepts for processing machinery will enter their useful state only in 5 to 10 years, and – if successful – remain in productive use thereafter for a couple of decades. It is essential therefore that the engineers involved in this innovation have a wide and long range scope of the impact of technology on the environment. They need reliable data and well founded models of the behavior of nature, in order to direct technology with carefully balanced compromises for providing performant products with a minimum consumption of resources. Where to get these data?
The partners to provide data on sustainability are scientists in specific areas, as biology, environmental sciences, toxicology, social sciences, and many more. On this scientific level, data and statistics abound. Different however is the situation in the integral assessment of sustainability, which affords compromises between different scales, ratings, and targets. In this area, science tends to promote momentary trends that change with the seasons of the year. This is the weak point for any taking care of sustainability when working on long range technical developments. While setting targets for technical development, there is simply no room for wishful, esoteric ideas.

To fill the gap between the day-two-day changing preferences of sustainability as a public issue, and the long term commitment in developing technology for the welfare of mankind, Dr. Marion Tobler was integrated as a specialist in environmental sciences to our Institute for Manufacturing Automation. She invested years into getting acquainted with the terms and the culture of the textile industry, and established communication with the industry, from top to shop floor in production plants. Over a period of 10 years, with the support of students and graduates in environmental sciences and engineering, she collected, checked and researched data on textile manufacturing processes and products. This long term assignment was made possible by a grant of the Hartmann-Müller-Foundation for Textile Research. The result is this compendium, which puts its focus on the most important fibers and processes. Given by the availability of scientific data, these come primarily from Europe and The United States.

This handbook is a compilation of technical, economical, and environmental data. It describes the aspect of ecology in a complex, interlaced network of value adding processes and businesses. There is no intention to introduce a change of opinion or behavior of the public, and there is no promotion of specific solutions, as found in many publications on textiles and sustainability. It is a message on the state of science and technology, intending to contribute to the further development of sustainable products and machinery, within this fascinating area of technology.

Prof. Dr. Urs Meyer
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I Introduction to the Manual

What can be expected from a book dealing with sustainable textile production? Who will be the readers of such a manual and what are the aims of the book? To answer these questions the author will reveal her intentions in writing this book, which took about three years, and the development from the first idea up to the present work.

The motivation to write a book was since the beginning related with the habilitation project Prof. U. Meyer offered to me in the late 90’s. The idea to produce something physical, even useful to mankind was very appealing to me.

1. Reasons to write a manual

Ever since working in the area of sustainable development in combination with textile technology I found myself arguing slightly different according to the person I was talking to. My partners were farmers, marketing managers, environmental scientists, the LCA community, textile engineers, people from authorities and consumers in many parts of the world. So when the subject of the manual outlined, the question was: who will be the readers of this book? I recognized that people working in textile companies were not familiar with working conditions in agriculture. Those who take sustainable development as a philosophy were helpless in finding solid practices in industrial processes. Scientists focused on methods, data and a functional unit, underestimated the basic knowledge in the textile sector considerably. Cotton growers were not much interested in understanding what difficulties spinning companies had to deal with, as long they were paid a reasonable price for their cotton. Companies complained about unfair competition through national environmental legislation. Consumers believed only natural fibers are good fibers and economist wanted to have single figures or rules instead of time consuming LCA results which nobody understood. Engineers feared for losses in innovations, if they will be restricted to a Sustainable Development. Finishers were sick of being accused to pollute the whole world and wanted consumer’s to be educated. Marketing mangers believed Sustainable Development was not of any concern.
to them, an particularly not in their responsibility. Our societies have moved towards convenience living in many parts of the world. Youngsters do no longer know what material they are wearing a.s.o. The misapprehensions could be continued. The list is by no means meant not to blame people involved: my own pathway in research of this field is paved with many of this prejudices. I was lucky to meet many people, who were willing to make me acquainted to the real nature of things, though if I had to make up my mind in between different viewpoints.

Talking about sustainable development, I was confronted with more different believes than there are definitions stated in literature. Again and again I learnt how important communication is this field is. Even if I never intended to deal scientifically with the term, I had to define common understanding and take position.

2. About structure and readers

The question I had to go over and over again was: how can I transfer my knowledge to almost all people who might be interested in textile and apparel in relation to sustainable development. Knowing I have to fulfill superior academic requirements on one side, and the aim to make the results understandable to the majority of non academic involved persons, I was searching for groups of interests and groups of issues. I found the answer after several trials in the here presented structure.

Chapter II is dedicated to the sustainable development, a philosophy developed as scientific issue but also as believe of persons and organizations to be applied in practice. Here the reader is given a brief overview on the multiple definitions and understanding of the term. It shows how theoretical concepts are translated and simplified into applications for authorities and the private sector. Some commonly used instruments are introduced on how to identify, measure, quantify, and communicate environmental aspects in our every day life and in science. Specific attention in this area is drawn to the textile sector.

When writing I had both environmentally oriented managers and consumers in mind, but also the academic requirements for the background of the studies. Producers and consumers are given information about environmental
management systems and labeling systems, including environmental product declaration and eco design.

Basic information in form of a survey on the textile chain is presented in **Chapter III**. It starts with fiber production with its variety on raw material, followed by textile processing and technologies in yarn and fabric production. The greatest variation is found in finishing processing and technology, where many aspects of fashion, comfort and special properties are adapted. The manufacturing of apparel is directly oriented towards consumption, a process everybody is personally involved in. Interested consumers, authorities and also beginners in textile technology will find simple descriptions of production stages and thereby get access to the complexity of the “textile world”. They will get an insight into processing and an understanding of interactions along the value added chain. Environmentally oriented readers may find themselves confronted with options and limitations in process technology. Especially the part consumption and disposal are meant as sensitization to change the own behavior. For science this chapter represents the description of the system investigated. This overview does not claim to be complete, but to allow simple comparison for example by means of indicators. For sustainable development in practice, indicators are sufficient to develop strategies for a management or personal choices.

The survey represents a summary of my lecture for environmental scientists and engineers at ETH based on own research, seminars and workshops I organized in the area of textile technology and ecology as well as information from companies and from literature. Some aspects are highlighted and more detailed, because they represent basics or practical experiences gained in studies (see research program), whereof the results will be presented in later chapters of this book. These case studies will allow to read the book not only from the beginning to the end, but also to switch from chapter to chapter to find all information about a specific case study.

**Chapter IV** is based on the previous chapter and indicates ways to specify quality and functions of textile products on the individual process steps. Based on approved quality parameters in agriculture, company and trade, that are again highlighted and detailed in selected aspects, a simplified system for textile specification has been elaborated. The purpose of this highly structured system is to optimize textile processing based on measured, quantified quality and
through improved communication between business partners along the value added chain. If textile specifications are applied in electronic data exchange they represent a competition factor for the users, in superior process control and in faster in product development. A part of the textile specification is also suited for detailed information towards the consumer, to make an appropriate choice. Hence this section may be interesting for producers and advanced consumers.

The aim of the second part is to define functionality of products. Regarding the countless variations in apparel it is essential to adapt the functions of apparel to the desired use. To achieve a optimized match of processing and functionality is a major contribution to reduce textile waste and thereby add to sustainable development. The section provides information on how desired properties of a product can be achieved in specific processing and shows interactions among properties. Such knowledge is important for product development, which too often is driven by fashion only. It may become important also for readers who are especially interested in marketing (see chapter V).

The third part provides requirements for “Best available technology” (BAT), an activity of the EU for improved environmental protection. A BREF document has been published as mandate of the “Integrated Prevention and Pollution Control” (IPPC) with the European Union, focusing mainly on finishing processes. BAT is completed in this part with recommendations for all processes of the value added chain of textiles and apparel.

Basic environmental research as Life Cycle Assessment (LCA) of (almost) all succeeding processes is presented in chapter V with some variations. This represents the first and only assembly of process LCA, based on individual measurement and including all steps from cotton growing, spinning, weaving, finishing and consumption. The studies have been carried out between 1996 and 2005 and were calculated by means of the same software. The environmentally interested reader may be fascinated to be given accurate results. Nevertheless, as different methods have been applied, comparison is complex and requires a careful evaluation of the uncertainty, which is added to the results in a classical scientific form. As the results are highly related to scale & scope and functionality, they are also interpreted with this background. There is no need to emphasis that this section is especially dedicated to science, even if the results are interesting to all readers, whom I encourage to read carefully.

When drafting ideas for this manual, I noted: a simplified method for application: to develop. This was set without having a determined vision of its
Chapter I Introduction

nature. But since the beginning it was clear that full LCA was not the solution. Indicators seemed too vaguely and inventories were often confidential. Marketing strategies showed that existing methods have failed. My work as chairwoman in COST action working group on LCA in textiles provided an insight into European research activities and company’s practices of 19 nations. So I took the courage and developed the idea of ecological key figures. They are based on equations for individual processes along the value added chain, taking into account main specific circumstances in production as well as basic environmental impact assessment. I believe future oriented companies will prefer this instrument for quick calculation of environmental impacts. The scientific evaluation will state it as a simplified method, not as accurate as LCA, but based on available data from textile industry.

In Chapter VI a completely different viewpoint is introduced: the marketing perspective. As marketing is overwhelming in its economic importance, the consequences for sustainable development are indirectly influenced by its decisions. The push strategy coming from the value added chain has almost disappeared in favor of a pull strategy from product development and marketing, establishing new rules by working in a global environment. During many visits and a sabbatical in the USA I had the opportunity to add the American perspectives of the large merchants to the one of Swiss and European small and medium sized companies. Also markets and consumer’s behavior are compared in this chapter, allowing drawing some predictions from one to the other market. This chapter is important for consumers and product development. It must be considered also for scale and scope definitions of scientific studies, if they should be reality based.

Literature is cited after every chapter. There will be also some links who allow getting actual versions of documents cited in this book.

3. Thanks

First of all I want to thank Prof. Urs Meyer who offered me the opportunity to enter a new research area, to learn about textile processing and machinery and business processes. In his very special style Urs Meyer led his staff including me towards high responsibility in textile research. The cooperation with textile
engineers opened new horizons to me. By nominating me member of the research commission of the Swiss association of textile industry and editor of Klippeneck, he allowed me to establish an environment with excellent partners in industry for discussions about quality and functionality.

Prof. Theo Koller, who earlier referred my doctoral thesis, earns the great merit of educating me to become an environmental scientist by reason and heart.

In all the years of research I met many experts in textile technology on many seminars and congresses, who increased my knowledge with their valuable contributions. Among them I wish to give my special thanks to Dr. Ulrich Meyer, who guided me gently through the finishing processes. Prof. Petra Blankenhorn made me part of her interesting studies at Fachhochschule Albstadt Ebingen.

Invitations to Eastern Europe textile congresses, combined with industry visits, imparted me knowledge about this important textile area and its attempts towards a Sustainable Development (SD). I felt honored to be invited as first European expert on LCA to Thailand’s textile industry and authorities. The kind reception and the decided direction towards SD impressed me deeply.

I would not have been able to do research in cotton growing without the many stays at the International Textile Center in Lubbock and Texas Tech University. There I always was sincerely received and assisted by Dr. Dean Ethridge, Dr. Eric Hecquet, James Simonton and especially Pam Alspaugh, my friend and most valuable contact to the Texan farmers and ginners. Prof. Don Ethridge and Prof. Sukant Misra kindly filled my knowledge gap in cotton economics. Roy Baker and Alan Brashiers introduced me into cotton ginning processes. Dan Krieg, Dan Bowman, John Galaway and many other researchers from Texas Tech University supported me in understanding cotton growing processes. Among the farmers who provided special growing conditions for my students I wish to thank the Brosch family. My special thanks goes to LaRhea Pepper who hosted one of my students and confined him her organic cotton marketing.
During my annual stays in the USA I could take benefit of many discussions with Profs. Buvanesh Goshwami and John Abernathy at Clemson University, with Kay Obendorf and Prof. Anil Netravali at Cornell University and with Prof. Peggy Gutman at Philadelphia University. John Price and Leo Cui from USDA New Orleans supported my research directions with valuable critical remarks.

Prof. Subhash Batra from NCSU, who nominated me as member of fiber society, assisted my kindly with his outstanding experience in organizing my sabbatical at the college of textiles. During my stay in 2003 Prof. Nancy Cassil made her countless contacts to the textile industry available to me and earns the merit of making me understand US textile marketing.

Since 2001 I met many textile researchers from all over Europe during COST action 628 who allowed me to learn about the research in the 19 countries involved. First of all I wish to thank the chairwoman Prof. Eija Nieminen from Technical University in Tampere who started the action and enabled the European networking. She trusted me as much as to lay the guidance of working group 1 in my hands. Special thanks go to Dr. Maria Walenius Henriksson who was not only an excellent co-chair but became also a friend. I experienced great cooperation from many colleagues when coaching Task Force BAT within COST action. I cannot name all my colleagues in COST action who were willing to share their research but I highly appreciate all their cooperation.

For over 15 years I had the benefit in working with ETH students, who dedicated their education to textiles and environment and worked hard for good research results. Many of them found their way into this manual. Thank you all! Helene Zurbuchen from our staff at ETH assisted me in professional manner in quality measurement of fibers and yarns. Many valuable inputs from our staff have entered my research activities at ETH.

Working parallel to my academic career as a consultant in my own company provided me with experiences; I would never have attired in research. I consider the cooperation with our business partners as a privilege and wish to thank them for their valuable partnership.
Diana Hornung, my assistant and friend, spent endless hours in bringing the manual to the present form and was never tired to change the layout about my often changing ideas. Thank you.

My son Harry gave me support in taking and editing pictures and provided me with a super safe, ever operating computer. Finally my thanks goes to my husband Hans, who never was tired to listen to any issue in textile technology, about difficulties and worries, and who supported me and my work with his kind, caring manner.

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