Life Cycle Assessment of Textile Products, Eco-efficiency and Definition of Best Available Technology (BAT) of Textile Processing

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### Project details

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### Objective

**A. BACKGROUND**

The Environmental Importance of Textile Products:

The annual production of textile fibres is about 50 million tonnes. The production of natural fibres is about 25 million tonnes and about the same amount are man-made fibres. The share of fibres used for traditional textile products, such as clothing and interior textiles, is about 2/3 of the total fibre production. The rest is used for technical and hygiene textiles, such as filters, insulators, composites and diapers. The production of technical textiles is growing rapidly.

Cotton is a cellulosic natural fibre and the total cultivation area is some 33 million hectares with an average annual production of 20 million tons of raw fibres. Cotton is virtually CO2 neutral, renewable, and recyclable and can be burned to release stored solar energy. Cotton growing requires in average 7 tonnes water for irrigation and about 45 MJ/kg energy is required for farming, transportations and purification processes to produce baled cotton fibres to be used as textile raw materials. About only 30-40% of harvested raw cotton can be used as textile fibres; the rest is cottonseed and other by-products as well as waste. A great number of different pesticides are used for cotton growing. These pesticides may be toxic and have harmful effects on the environment. The production of organic cotton, e.g. where no pesticides are used, is less than 1% of the total cotton production.

For almost all countries producing wool, wool fibres are secondary products of sheep meat production, which makes it difficult to allocate the energy consumption in fibre production. Furthermore there is no data available on the energy needed to produce the applied pesticides and the energy content of manure in sheep farming.

Synthetic fibres are produced of non-renewable resources, such as crude oil and natural gas, by industrial processing. The data available on environmental effects of the production processes is based on publications by the industry.

Polyester fibre is the most widely used synthetic fibre in the world. In 1995 the world production of synthetic fibres was 20,2 million tonnes, whereas polyester fibre production accounted for 11,9 million tonnes. The most widely used polyester fibres are made from the linear polyethylene terephthalate, PET. The starting reactants for the polyester processing are products of downstream petrochemical operations. Thermoplastic polyester can be selectively engineered at all the basic process steps: polymerisation, fibre formation and fabrication for textile apparel, furnishing, industrial, tyre and carpet markets. The total energy consumption in polyester fibre production is 109 MJ/kg fibres, where 63 MJ/kg is process energy requirements and 46 MJ/kg corresponds to the energy of material resources; the production of 1 kg fibres consumes 1,14 kg of non-renewable fossil resources.

In the screening of the selected chemicals, some have been found to have high or medium potential of creating problems, if discharged without prior treatment or if no precautions have been taken to mitigate negative effect on the working
environment.

Acrylic fibres are the second important group of synthetic fibres and it is produced of acrylonitrile. Oxygen and ammonia are catalytically converted to acrylonitrile operating at high temperatures under pressure. The world production of acrylic fibres was 2,3 million tonnes in 1984 and represented 6,5% of the total fibre production. The total processing energy plus energy for production of acrylic fibres is 157 MJ/kg of fibres.

In the screening of the selected chemicals used in synthetic fibre production, some at least have been found to have high or medium potential of creating problems, if discharged without prior treatment or if no precautions have been taken to mitigate negative effect on the environment.

Viscose is a man-made fibre manufactured in the basis of cellulose fibres. It belongs to the class of fibres called regenerated fibres, made of natural polymers. About two thirds of the viscose produced is in the form of staple fibres and a wide range of deniers and several different fibre cross-sectional shapes are available in straight or crimped fibre. The world production of viscose fibres is about 3 million tonnes, of which the staple fibres correspond to 2,075 million tonnes. The basic raw material for cellulosic fibre production is wood pulp and about 3 kg of wood is required to produce 1 kg of viscose fibres. Viscose consists of 10% cellulose, 6% sodium hydroxide and 84% water, carbon disulphide and additives. Depending on the type of fibre and alkaline process used, between 220 and 400 kg of carbon disulphide is needed to produce 1000 kg of fibres. The energy requirement in viscose production is between 68-96 MJ/kg of baled staple fibres. The wood represents energy by the feedstock contained; 3 kg of wood thus represents 36 MJ/kg. About 420-750 litres of water is needed per kg viscose fibres produced for the processing. In the screening for environmental and health effects of the used chemicals in viscose processing some of them have been found to have a potential of creating problems, if they are discharged to the recipients without prior treatment.

The nature of natural, regenerated and synthetic fibres is very different and they cannot therefore replace each other. Synthetic fibres can be technically modified but they lack some of the characteristics of natural fibres, such as moisture absorption capacity. There are also some major regional environmental aspects associated with fibre production, such as the land use and irrigation problems in cotton cultivation.

About 4,7 million tonnes of textile fibres are consumed in the EU countries. The share of regenerated and synthetic fibres is 60%, 30% of cotton and 10% of wool.

Industrial processing and use of textile products also have considerable amount of environmental impacts and require remarkable resources of energy and materials. Reduction of material and energy flows as well as the amount of total consumption is major elements of sustainable development. The use of natural resources in industrialised countries should be reduced by Factor four within the next 20-30 years and by Factor ten within the next 50 years in order to maintain sustainable development in a global scale. Environmental impacts should thus be evaluated along the whole life cycle of products, including raw material extraction, industrial processing, transportation, use, maintenance and waste management.

Life Cycle Assessment (LCA) of Textile Processing and Products:

LCA is a relatively new and developing science which is regarded as an important tool to evaluate the environmental impact of textile processing and products. The major reasons for performing LCA are:

- to obtain quantified and reliable information for the emotive debate on the environmental impact of textile products to be used by industry and policy makers,
- to highlight areas where information on the environmental impact is still unknown or uncertain,
- to enable considerations for reduction of material and energy flows along the textile life cycle,
- to enable comparisons between different textile materials, provided that products are used for the same purposes.

However, LCA of textiles and textile processing presents certain problems, such as:
- life chains with long transport distances, like the cotton route from Asia to Europe,
- product life time evaluation as a major ecological factor and highlighting the synthetic versus natural fibre comparisons,
- textile products and processing have relatively complex relationships between products, by-products and waste,
- potential evaluation of dematerialisation,
- data gaps on fibre processing and cultivation chemistry.

Eco-efficiency and Best Available Technology of Textile Processing:

Eco-efficiency and sustainable development concepts were popularised by the World Business Council for Sustainable Development in 1992. The concepts express the need that the economic development should be accompanied by its long-term sustainability with respect to economy, ecology and society. Various analysis tools and methods serve to evaluate effects and side-effects of textile processing and products, as well as the resulting risks and benefits with respect to social acceptance, inherent safety and finally eco-efficiency. In general, the term efficiency describes the relation between benefits and burdens of a system. If the benefit is defined as the added economic value (e.g. in Euro) and the burden as the resulting environmental impacts (e.g. CO2 emissions, "ecological impact points"), efficiency may be defined as eco-efficiency. In other
words, eco-efficiency may be defined as the ratio of an economic performance indicator and the resulting ecological impact indicator.

Eco-efficiency = Economic benefit (Euro)/Ecological burden (Points).

System boundaries for textile technologies with less environmental burden may be defined as Best Available Technology (BAT). This Action aims to develop ecological impact indicators, as well as to define BAT for production of selected textile products and their processing.

Both concepts, eco-efficiency and BAT, aim to decrease emissions and to intensify the use of energy and material resources, e.g. dematerialisation.

A new concept, immaterialisation, has recently been introduced in the context of sustainable development. Immaterialisation aims to reduce the total amount of consumption. This will be achieved by changing social behaviour of consumers towards services instead of products and by increasing the exploitation of modern information technology. The life time of products and recycling/reuse potential of products are of major importance in this context.

Current LCA, BAT and eco-efficiency activities:

First guidelines for LCA were published by SETAC (1993) and the Nordic Council of Ministers (1995). Since 1993 ISO-TC 207-SC 5 has been working on standards for LCA methodology and it published first standards in 1997. Presently 45 countries (most of them are European countries) are cooperating on this issue and the number is increasing. ISO has also been working on the development of environmental declaration standards for products.

The current efforts of ISO are, however, directed to the general development of LCA methodology and they do not consider special aspects of the textile chain. In specific textile issues like dematerialisation, product life time/quality, process and cultivation chemistry, land use, logistics and energy, are a matter of significance and they shall be considered within the framework of LCA improvement for these sectors.

Eco-efficiency evaluations with suitable indicator development have just recently been started in different sectors, like in chemical and metal industry. The eco-labelling by the EU and Nordic countries, as well as by private research institutes (Oeko-Tex), have highlighted and evaluated some major environmental impacts in textile processing. They do not, however, include economic performance indicators.

First BAT studies on textile wet processing have been carried out by certain European countries (for instance Finland). The studies were part of drafting the Best Available Technique (BAT) Reference Documents for the European IPPC bureau (European Integrated Pollution Prevention and Control Bureau), according to the General Outlines set by the IPPC BAT Information Exchange Forum, IEF.

The Proposed Cross-sector COST Action:

In order to overcome some of the problems presented above and because the research effort is fragmented between the sectors in the chain, a Cross-sector COST Action is required in order to coordinate activities across the whole textile processing and products chain in different countries and by cooperation between the institutes and industries concerned. This COST Action will create a multi-disciplinary forum for the exchange of ideas and harmonisation of methodologies. Such a forum will consist of:

- the COST Action management committee,
- multi-disciplinary Working Groups drawn from the fibre production, textile industry and trade, industrial laundering as well as specialists from outside these areas.

Links will be established to other European and international activities, such as the International Standards Organisation’s ISO 14000 standards for environmental management and LCA, as well as the research project to define the European BAT reference levels for textile wet processes according to the IPPC (Integrated Pollution Prevenve and Control) directive, organised by the European Association of Textile producers (EURATEX). Institutes for the European and Nordic Eco-labelling will also be connected to the project.

No other similar projects for textiles have been started within the EU research programmes or within COST or EUREKA activities. Positive methodical complementarity is foreseen in the COST Action E9 “Life cycle assessment of forestry and forest products”.

B. OBJECTIVES AND BENEFITS

The main objectives of the Action are to expand multi-disciplinary life cycle assessments to cover the whole fibre production and textile product chain, as well as to develop eco-efficiency indicators for the different phases in the textile product chain. Organisations for the European textile industry, as well as separate textile companies, have been involved when defining the objectives of the Action.

The reasons for the Action are:

- there is a need for a wide first hand environmental database of the textile product chain,
- LCA methodology development and comparison is necessary due to the need for a simplified and balanced approach within
the fibre production and the textile products sector,
-tools for comparisons of present technologies and practices with cleaner applications, including the economic effects, are required,
-LCA and eco-efficiency indicators will contribute to the improvement of processes and products,
-there is a need for development of international criteria for the environmental declaration of textile products.

The combined benefits of the Action will be to:
-bring together a multi-disciplinary and multi-cultural discipline under one umbrella,
-coordinate the approach to LCA within fibre production and textile products sector,
-improve data collection and exchange,
-develop indicators for the whole textile products chain in order to improve the environmental performance of the associated industries,
-to participate in the development of environmental declaration standards for textile products,
-establish a European forum on LCA and eco-efficiency in fibre production and textile products.

Initial objectives are to:
-propose methods and guidelines for a simplified and balanced LCA for textile products chain,
-propose methods to compare textile products, produced for similar end-use, with environmental criteria,
-consider dematerialisation and immaterialisation methods and practices along the whole textile chain,
-define system boundaries for cleaner textile processing as process related BAT levels,
-suggest criteria for environmental declaration standards for ISO,
-propose calculation and allocation rules for dematerialisation, recycling, energy generation and disposal.

C.SCIENTIFIC PROGRAMME

Cross-sector and multi-disciplinary exchange of knowledge originating from ongoing research activities in Europe is an important aim of all COST Actions. This COST Action is intended to encourage cooperation of ongoing and prospective European research regarding textile ecology. A multi-disciplinary approach is needed to reach the objectives and experts will be drawn from various background organisations, such as textile technology and chemistry, environmental research, eco-labelling.

To cover the topics listed below, Working Groups, research tasks and networks will be established. Because of the fast developing nature of this science, it is also necessary to bring experts in particular areas together for intensive development sessions. These activities will be coordinated by the management committee of the COST Action.

All research areas have strong interactions between each other.

Suggested Working Groups:

WG 1. LCAs on the textile products chain

This Working Group will develop a proposal for a simplified life cycle assessment on the textile products chain for a focused group of products: bed-linen, t-shirts, knitwear and terry-fabrics made of cotton, polyester, wool, viscose and acrylic fibres or of their blends. The fabric production processes covered by this WG are fibre production, spinning, knitting and weaving and wet processes, such as dyeing and printing. Washing and laundering techniques will also be examined, as well as recycling and disposal phases.

Five different types of fibres will be examined: cotton, wool, polyester, acrylic and viscose. There will be an effort to promote pesticide-free growing techniques and availability of production data of an alternative technology for synthetic fibre production.

Alternative technologies for spinning, knitting and weaving processes will be examined and compared in order to reveal best environmental practices, with special focus on material recycling and energy reduction.

Wet processing, e.g. pre-treatments, dyeing/printing and finishing, chemistry and technology will be examined for best environmental practice definitions and suggestions, with special focus on enzyme technology, waste-water purification and recycling techniques.

Alternative washing and laundering techniques will also be looked at with a special focus on industrial laundering processes for
bed-linen and terry-towels. Laundering chemicals will be evaluated in order to reveal best environmental practices. The durability of textile products for industrial laundering will also be studied.

This group will also look at the following:

- long transportation routes from fibre production sites to European textile companies,
- comparison of the importance of regional to global environmental impact,
- rate-of-use of textile products with main durability factors,
- quality and availability of data.

Evaluations and comparisons will be made to present eco-labelling criteria for textile products. Suggestions will be developed for environmental product declarations in cooperation with the national and international standards organisations, such as CEN and ISO. A general method to evaluate and compare textile products with environmental criteria will be developed for proposals.

WG 2. Dematerialisation of the textile products chain

This Working Group covers topics related to reduction of material and energy flows within the whole textile products chain. Specific calculation and allocation rules will be developed for dematerialisation, including recycling and re-use potential along the production and use phases of the textile products chain.

Examples are:

- exploitation of solid wastes for energy production: The heat content of solid wastes can be exploited by adopting specially developed combustion and gasification processes,
- recycling of solid textile waste: recycled fibres from spinning mills and cutting/sewing trims to be used for secondary textiles, such as insulator pads, pallet covers,
- recycling and reuse of products at the end of their life-time: development of new technologies and practices,
- process waste water analyses with a special focus on chemical recycling potential,
- examination of an alternative, e.g. plasma technology, to improve fibre surface reactivity towards dyestuffs and chemicals, as well as to reduce energy and water consumption and process emissions.

WG 3. Eco-efficiency indicators and BAT definitions

This Working Group will look at the whole textile products chain in order to define system boundaries for textile processing with less environmental impact, taking new “cleaner” technologies into consideration. Present practices will be compared with “cleaner” alternatives, and the economic consequences will be studied when present technologies are compensated with “cleaner” ones. Common rules for calculation of these eco-efficiency indicators will be proposed. This Working Group will also present criteria for the ISO standard development on environmental product declarations for textile products. The criteria will be based on LCA, BAT and eco-efficiency studies in this Action.

Examples of these so called cleaner technologies are:

- enzyme technology in cellulosic fibre modifications in order to improve dyestuff fixation rate and some physical properties of fibres,
- plasma technology in order to reduce water consumption in wet-processing,
- recycling of process chemicals.

D. ORGANISATION AND TIMETABLE

Organisation

The implementation of the COST Action is supervised and coordinated by a Management Committee according to the “Rules and Procedures for Implementing COST Actions”. The Working Groups indicated above will perform the practical work.

Reference groups will be formed in each participating country of selected textile companies, representing the main research fields within this Action. Researchers in the Action Working Groups will also participate in the reference groups at national level. National associations for textile industry, as well as standardisation and eco-labelling organisations will be represented in reference groups.

Timetable

The duration of the Action is planned for four years, mainly due to problems in collecting data with sufficient quality for life cycle assessments.
The Management Committee of the Action will organise annual meetings where Working Groups will report on research results and agree on goals for the following year. All Working Group researchers and members of Reference Groups will be invited to the annual meetings.

Action Milestones
The researchers participating in the Action will carry out research activities in 2-3 Working Groups and in the work of national Reference Groups. Working Group meetings will be organised four times a year and national Reference Groups will also meet four times a year, if required.

E. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: Finland, Greece, Belgium, Spain, Sweden, Switzerland and the United Kingdom.

On the basis of national estimates provided by the representatives of these countries and taking into account the coordination costs to be covered by the COST budget of the European Commission, the overall cost of the activities to be carried out under the Action has been estimated roughly at EUR 12 million at 2000 prices.

The estimation is valid under the assumption that all the countries that have indicated their interest in the Action, but no others, will participate in the Action. Any departure from this will change the total cost accordingly.

F. DISSEMINATION AND VALORISATION OF RESULTS

Dissemination of results
The results of the Action are aimed for use by research institutes in textile and environmental sciences, as well as by the textile companies in Europe.

A website for the Action will be established and maintained. The Action will also arrange annual meetings for all Action participants and national Reference Groups will nationally inform about the Action proceedings and results in cooperation with national Associations for Textiles and Textile Maintenance industry.

The Action research project proceedings and results will be published in textile journals, conferences and seminars on a regular basis. The index will be introduced to public media in cooperation with European and national textile associations as well as eco-labelling and standards organisations.

Assessment of results
Collection of high quality data on environmental impact of fibre and textile production is in a development phase, since no site-specific data has, so far, been available of major natural and synthetic fibre production. No systematic assessments have, either, been made on the major impact phases in the textile product life chain, e.g. no guidelines on "critical points", as major targets for cleaner technology applications are available. No international consensus has been reached for the life cycle impact assessment methodology; problems still exist in weighting different impact categories and local, regional and global impacts to each other. Specialists in LCA methodology agree, however, that product specific impact assessments should be developed, in order to collect high quality environmental data.

Eco-labelling, such as the EU eco-label, has been developed to become the major instrument in promoting markets for products with less environmental impact. Results of a recent study, carried out at the Tampere University of Technology, show, however, that no sufficient data is, at present, available on most common textile products, for eco-labelling purposes. A wide environmental data collection of textile products has to be carried out in order to increase eco-labelling potential for textile products of European origin.

This Action will support the development of environmental declaration criteria, carried out by ISO, for textile products.

Environmental declarations are based on LCA studies and, unlike eco-labelling, allow product comparisons with credible criteria.

The life cycle assessment, in association with a wide data collection, will support and increase markets of European textile products by introducing quantified and reliable information on the environmental impact of textile products. LCA will highlight areas where information on the environmental impact is still unknown or uncertain, as well as enable considerations for reduction of material and energy flows along the textile life cycle, and comparisons between different textile materials. Imported textile products from low-price production countries approach the quality level of European textile products, especially in consumer products. Environmental values presented with credible arguments can crucially improve the product competitiveness.

Eco-efficiency evaluations on economic consequences of replacing present technologies with cleaner ones will support the competitiveness of European textile companies, which operate according to the principles of sustainable development. Development of ecological impact indicators for textile processes is carried out in association with the life cycle assessment studies of the Action.

The Action will also produce a unique and wide database on European fibre and textile production processes and on associated environmental impacts, including textile maintenance.
The LCA and eco-efficiency studies will serve the interests of the textile industry in order to produce relevant environmental data on present textile technology in Europe, as well as in preventing developments of regulations, that would compromise the competitiveness of the European textile industry.

Coordinator

N/A

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