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Life Cycle Assessment of cotton/polyester fabric in B05 company

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1 Introduction

The work documented in this report is part of the project "Evaluation of the effect of the IPPC application on the sustainable waste water management in textile industries (Towef0)" funded by European Commission as a shared cost RTD project in the 5th Framework Research program, Energy, Environment and Sustainable Development, Key action 1 Sustainable Management and Quality of Water, Treatment and purification technologies, Waste water treatment and reuse.

The project objective is to establish a multicriteria integrated and coherent implementation of Good Environmental Practices (GEP) and to promote the efficient use of resources within textile finishing industries characterised by large use of water, taking into account the treatment of industrial waste water effluent (Urban Waste Water Treatment Directive 91/271 EEC) and the impact of the final discharge to the water recipient bodies (Water Framework Directive COM (98)).

Within this framework ENEA-PROT-INN conducted detailed LCA studies on selected Italian and Belgian industries in order to estimate the potential impact on the environment of specific company processes, evaluate the environmental effects of alternatives scenarios of water management and develop a database of Life Cycle Inventories of textile production processes and chemicals.

Partners of the project were: ENEA, the Italian National Agency for New Technologies, Energy and the Environment, Vito, a Belgian research centre for the industry, Centexbel, a research centre for the Belgian textile federation, the Joint research Centres of Siviglia and Ispra, Lariana Depur S.p.A., a private Italian company, Ecobilan, a private French company and Lettinga Associates Foundation (LeAF), a Dutch foundation for environmental protection and resource conservation.

In this document LCA methodology has been applied to selected cotton fabric products within B05 company.

2 Goal and scope definition

2.1 Goal of the study

The main goal of this LCA study is to quantify the environmental performance of selected textile production processes within B05 company identifying the potential environmental critical points.

The results achieved in this study will be used to support the identification of environmental favourable technologies/strategies in textile finishing industries, to evaluate different wastewater management scenarios and to develop a database of inventory data of textile processes and chemicals to be used with a industry specific user friendly environmental assessment software to be developed by Ecobilan within the project Towef0.

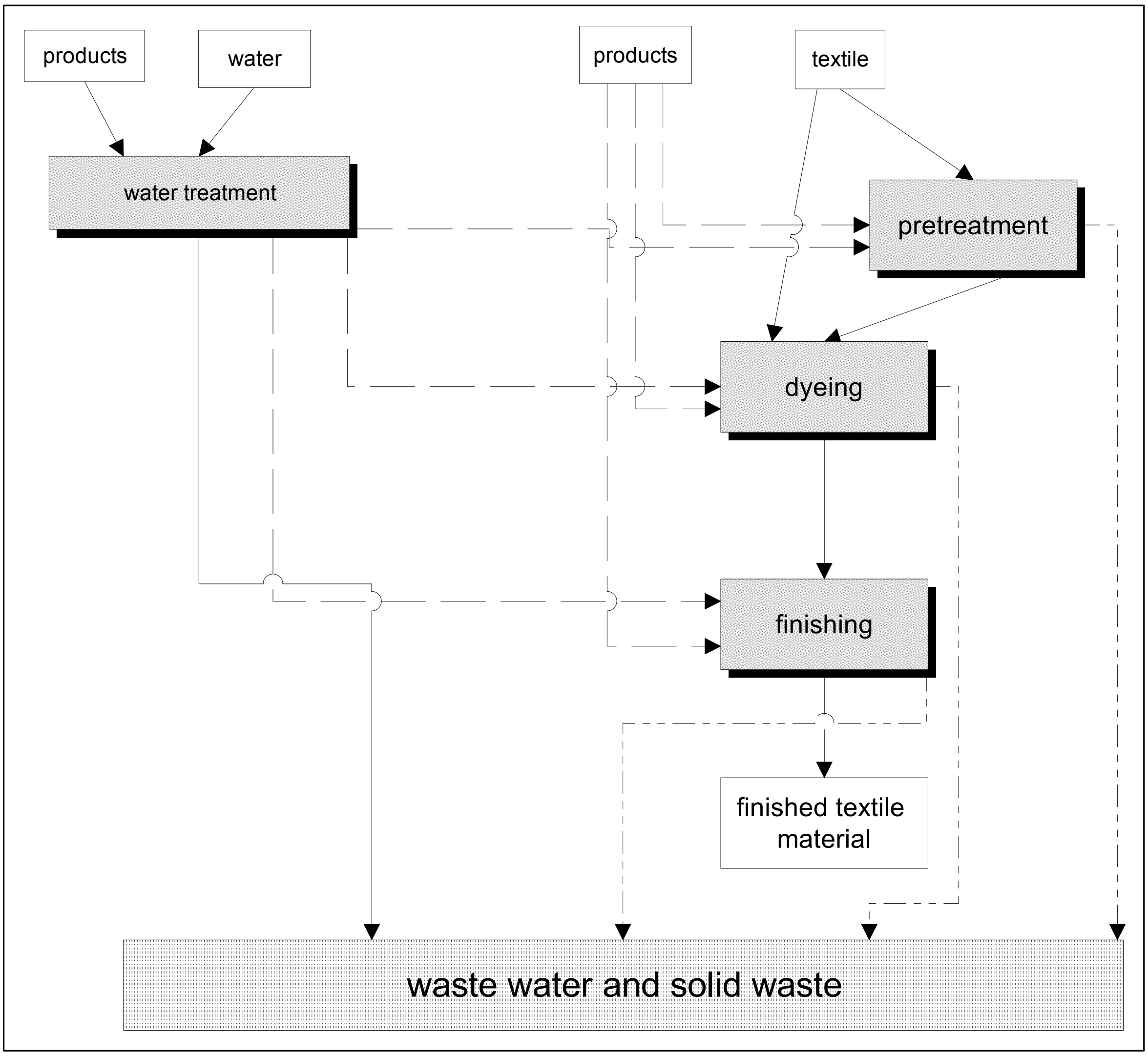
This study has been performed according to the requirements of ISO 14040 standards [1-4] by FEBE EcoLogic. The study commissioner was the European Commission which funded the Towef0 project. Researchers and technicians working in textile sector were the intended target of this study.

2.2 *Scope of the study*

2.2.1 General description of the systems

B05 is a Belgian company. Its annual production is over 6300 tons of fabric mainly made of cotton and flax (3150 tons processed per year), kermel (315 tons per year) and other textile products (2835 tons of CO/PES, CO/PA, CO/Flax, CO/Wool and CO/Viscose).

The general organization of the company production departments is highlighted in the following material flowchart.



A more detailed description of B05 company is available in Process Identification and data Collection Sheet (PIDACS) of B05 company.
In this study the cotton/polyester fabric(combined CO/PES) product is analysed: pre-treated by wetting/bleaching and, mercerising, dyed with combined dyeing and finished.
For a better understanding of the report, a short description of the textile wet processes is presented hereafter. The description is extracted from the reference Document on Best Available Techniques for the Textile Industry [5].

Pretreatment

Pretreatment processes should ensure:

- the removal of foreign materials from the fibres in order to improve their uniformity, hydrophilic characteristics and affinity for dyestuffs and finishing treatments,
- the improvement of the ability to absorb dyes uniformly (which is the case in mercerising),
- the relaxation of tensions in synthetic fibres (without this relaxation of tension, unevenness and dimension instabilities can occur).

Cotton pretreatment includes various **wet operations**, namely: singeing, desizing, scouring, mercerising (and caustification), bleaching. Some of these treatments are obligatory steps only for certain make-ups (e.g. desizing is carried out only on woven fabric). Moreover some of these treatments are often combined together in one single step in order to respond to the need to reduce production time and space as much as possible.

When the material has to be dyed in dark colours it can be directly dyed without need of **bleaching**. On the contrary, bleaching is an obligatory step when the fibre has to be dyed in pastel colours or when it will need to be subsequently printed. In some cases, even with dark colours a pre-bleaching step may be needed, but this is not a full bleaching treatment.

Bleaching can be performed on all kinds of make-ups (yarn, woven and knitted fabric). The most frequently used for cellulosic fibres are oxidative bleaches, namely hydrogen peroxide (H_2O_2), sodium hypochlorite (NaClO), sodium chlorite ($NaClO_2$).

The main environmental issues associated with cotton pretreatment arise from emissions to water. The characteristics of the emissions vary according to a number of factors: the make-up, the sequence adopted, the fact that some treatments are often combined in a single step, etc. In a typical mill processing cotton or cotton-blend woven fabric, desizing represents the main emission source in the overall process.

Mercerising is carried out in order to improve tensile strength, dimensional stability and lustre of cotton. Moreover an improvement in dye uptake is obtained (a reduction of 30 – 50 % of dyestuff consumption can be achieved thanks to the increased level of exhaustion).

Mercerising can be carried out on yarn in hanks, woven and knitted fabric through one of the following different treatments: mercerising with tension, caustification (without tension), ammonia mercerising.

Caustic soda mercerising is the most commonly applied mercerising technique. Cotton is treated under tension in a solution of concentrated caustic soda (270 - 300g NaOH/l, which means also 170 – 350 g NaOH/kg) for approximately 40 - 50 seconds.

Combined dyeing

Vat dyes have excellent fastness properties when properly selected and are often used for fabrics that will be subjected to severe washing and bleaching conditions. Vat dyes are normally insoluble in water, but they become water-soluble and substantive for the fibre after reduction in alkaline conditions (vatting). They are then converted again to the original insoluble form by oxidation and in this way they remain fixed into the fibre.

In all cases, oxidation and after-treatment follow. After-treatment consists in washing the material in a weakly alkaline bath with a detergent at boiling temperature.

Continuous processes are used almost exclusively for dyeing woven fabrics and to only a small extent for knitwear. The most commonly applied continuous process is the pad-steam process.

The textile is padded with the aqueous dye dispersion in the presence of anti-migrant (polyacrylates, alginates, etc.) and dispersing/wetting agents, if required. After drying, the fabric is passed through a chemical padder, which contains the required amount of alkali and reducing agent and is fed immediately to a steamer. The material is finally rinsed, oxidised and soaped in an open-width washing machine.

Polyester fibres (PES) are made of linear macromolecules containing at least 85 % of an ester in the chain. The fibres have a very high degree of crystallinity, which allows for excellent heat-resistance and other mechanical properties. On the other hand, this compact structure inhibits the diffusion of the colourants into the fibre during dyeing. As a result, fibres cannot be dyed below 100 °C, unless dyeing accelerants (so-called carriers) are used. Carriers are harmful for the environment and in many cases are toxic for humans.
Provided that alkali-stable dyes are used, dyeing in alkaline medium (pH 9 - 9.5) is possible. This technique has been developed in order to counteract the migration and deposition of oligomers typical of PES fibres. In fact, oligomeric components (cyclic trimers of ethylene terephthalate are especially harmful) tend to migrate out of the fibre during dyeing, thus forming with the dye agglomerates that can deposit on the textile or on the dyeing equipment.

Finishing processes
The term "finishing" covers all those treatments that serve to impart to the textile the desired end-use properties. These can include properties relating to visual effect, handle and special characteristics such as waterproofing and non-flammability.
Finishing may involve mechanical/physical and chemical treatments. Some finishing treatments are more typical for certain types of fibre (for example, easy-care finishes for cotton, antistatic treatment for synthetic fibres and mothproofing and anti-felt treatments for wool). Other finishes have more general application (e.g. softening).

A detailed description of the studied systems is available in chapter 3.2.
A general description of the equipments used for all textile processes is given in the Reference Document on BAT for Textile processing [5].

2.2.2 Function

The main function of the studied systems is the pre-treatment, dyeing and finishing of cotton/polyester fabric, processed to reach the required commercial characteristics respecting the worker safety and the emissions limits according to the law in air, water and soil.

2.2.3 Functional unit and reference flow

The chosen functional unit is the pre-treatment, dyeing and finishing of a weight unit of cotton/polyester fabric, processed to reach the required commercial characteristics, respecting the worker safety and the emissions limits according to the law in air, water and soil.
The reference flow is 100 kg of cotton/polyester fabric.

2.2.4 System boundaries of product system

The system boundaries of the two studied product alternatives are shown in Fig. 2.1. the processes included in the analysis are included in the system bold line.

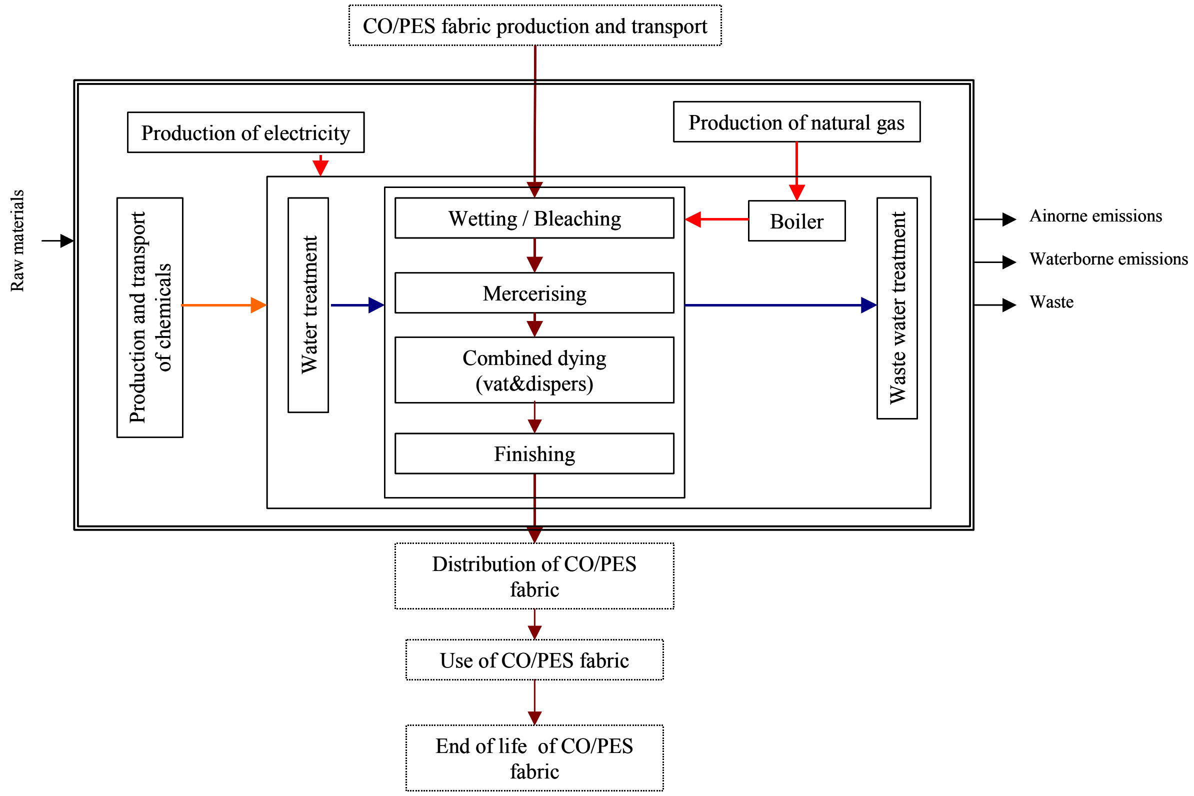


Fig 2.2 System boundaries of B05 product systems.

The processes excluded from the system boundaries are:

- raw cotton/PES fabric production processes, including the relative transports;
- all the product life cycle phases external to the company gate;
- the production and manufacturing of all equipments, machineries and capital goods used in the industrial processes, as commonly accepted in LCA.

2.2.5 Data categories

The choice of data categories has been made in relation to the impact categories and characterization factors adopted. They include the macro categories of energy, raw materials, chemicals and emissions in air water and soil.
Different data sources were used in this study:

Company specific data:

- wetting and bleaching
- mercerising
- continuous dyeing of CO/PES
- combined dyeing of cotton fabric
- finishing

TEAM 3.0/Ecobilan data:

- production of electricity (the Belgian electricity mix has been used to model the production processes);
- production of natural gas;
- transport processes;

- boiler: general model whose process parameters and efficiency are adjusted to B05 company.

Detailed hypotheses on the electricity production and on all the models used in this study are available in TEAM 3.0 modules database [6].

Lariana Depur data:
- All the centralised Waste Water Treatment Plant data.

Production of chemicals:
- TEAM 3.0/Ecobilan
- other LCA commercial databases and literature [7-11]
- data collection from manufacturers;
- surrogate data [12] for performing sensitivity analyses and check the influence of the missed data.

2.2.6 Criteria for initial inclusion of inputs and outputs

All the inputs and outputs available in PIDACS were included in the study.
Because of the large amount of base chemicals used for pre-treatment operation in textile wet processing, it was decided to include in the analysis the chemicals production. A comprehensive review of the chemicals Life Cycle Inventories (LCI) available in commercial databases has been performed and direct contacts with the main textile chemicals manufacturers have been started up. In case of lack of data, production of chemicals was excluded from the product system. In the Interpretation phase of the LCA study, a sensitivity check was made concerning the lack of data about production of chemicals. Surrogate inventory data about the production of organic chemicals [12] were used to evaluate the sensitivity of the product system to these data (see Chapter 5.2.2.2).

2.2.7 Data quality requirements

The on site data gathered in this study have the following characteristics:
- Time related coverage: All the B05 data are related to year 2000;
- Geographical related coverage: the data are related to Belgian companies.

To model the product system several assumption were necessary:

Main assumptions within the company boundary:
- <u>Steam production</u>

The annual company steam consumption is measured and reported on the B05 PIDACS as well as the annual production of processed fabric. Lacking process specific data on PIDACS, the steam consumption was so allocated to the reference flow on a mass basis. Process specific wastewater effluent
Due to data unavailability the wastewater effluent from the company specific processes has been characterized only with measured COD concentration.
- <u>Electricity consumption</u>

The annual company electricity consumption is measured and reported on the B05 PIDACS. The electricity consumption of specific processes has been calculated as [absorbed power] x [working time]. The electricity consumption for lighting and general services has been neglected, as generally accepted in LCA studies, because it is not relevant for the specific objectives of this study.

- General facilities

Due to data unavailability in PIDACS general facilities are not included.

- Solid waste

Due to data unavailability in PIDACS solid wastes are not included.

- Airborne emissions.

Due to data unavailability in PIDACS airborne emissions are not included.

- Transport of chemicals

Due to data unavailability in PIDACS transport processes are not included.

Main assumptions for production of chemicals:
The inventories available in TEAM 3.0 database have been included in the study; the following databases were checked in addition to the TEAM 3.0 one:

- SimaPro [7];
- KCL Eco [8];
- IVAM [9];
- Boustead model [10];
- GaBi 3.2 [11]
- Specific industry data.

Main assumptions for Lariana waste water treatment plant (WWTP):
It was assumed that the potential environmental impacts of WWTP processes are mainly due to the production of the energy needed in the plant and to the emission of the treated effluent into the environment. The impact of chemicals production has been neglected. These hypotheses were based on results of previous LCA studies of ENEA [14].
The potential environmental impacts for treating the waste water of the studied product systems have been considered proportional to effluent mass.
Direct CO_2 emissions in the environment from Lariana WWTP processes have not been considered (according to IPPC guidelines) [14].
Because it was not possible to have information on the specific contaminants of the product systems' water effluents, the evaluation of the potential impact connected to the release to the environment of the treated water effluent has been calculated considering the effluent mass of the specific product system and the contaminant concentration of the treated WWTP effluent.
(The Belgian electricity mix has been used to model the electricity production processes).

2.2.8 Impact assessment methods

The impact categories used for the analysis of the product systems are indicated in table.2.3

Tab. 2.3 Impact assessment categories

Category	Unit
CML 92-Air Acidification	g eq. H+
CML 92-Aquatic Eco-toxicity	1e3m3
CML 92-Depletion of non renewable resources	frac. of reserve
CML 92-Eutrophication	g eq. PO4
CML 92-Human Toxicity	g
CML 92-Terrestrial Eco-toxicity	t
IPCC-Greenhouse effect (direct, 100 years)	g eq. CO2
WMO-Photochemical oxidant formation (high)	g eq. ethylene
Reminders-Primary energy consumption	MJ

The chosen impact assessment categories are well know and accepted at international level: a short description can be found in TEAM software online documentation

2.2.9 Interpretation methods

In the interpretation phase of this study the potential environmental impact of the different processes has been evaluated, the significant issues have been identified and the contribution of the specific contaminant fluxes has been calculated. The sensitivity check focused on allocation rules (steam) and lack of inventory data for chemicals.

2.2.10 Critical review

Being a pilot study performed in a research project, this report has not been submitted to a critical review.

3 Inventory analysis

3.1 Procedures for data collection

Data were collected from B05 company with the Process Identification and data Collection Sheet (PIDACS) defined and used by the Towef0 project. The PIDACS contains information for the entire Towef0 project and a part of the data was extracted for the LCA study.
Flow-charts of the most representative production lines were identified on the basis of the PIDACS data.
Data collection was performed by Centexbel.
The elaboration of PIDACS data required further details concerning processes of B05 company. This information was obtained from Centexbel by e-mail contacts.

Data were implemented using predefined modules of the TEAM software. The modules were developed by Ecobilan and were specific for the textile finishing industrial sector.

The product system was completed using modules of the TEAM database and other bibliographical sources.

3.2 Qualitative and quantitative description of unit processes

The next chapters describe data collected for the inventory analysis. Data elaboration procedures are explained by the documentation of assumptions and allocation procedures.

3.2.1 Cotton/polyester wet processing and general facilities

Annex 00 describes general structure and content of the PIDACS.
In collaboration with Centexbel, the most representative production line was identified and depicted in the following flow-chart (Figure 3.1).

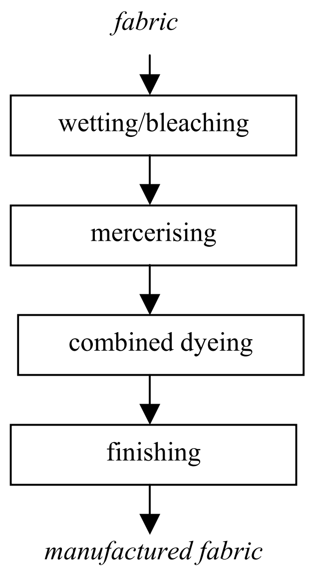


Figure 3.1 Flow-chart of the B05 production line

The equipment capacities are:

- pretreatment line: 1502 kg/h for wetting/bleaching on rakojet and 1360 kg/h on mercerising line.
- vat dyeing of CO and disperse dyeing of PES: 710 kg/h on hot flue and pad steam.
- finishing :lack of data.

The next paragraphs describe the data available in PIDACS, their elaboration and main assumptions of the LCA study. Data are always related to the above described capacities.

3.2.1.1 Water use

Table 3.2 shows the water consumption of the selected processes.

Table 3.2 Water consumption of processes

	Water consumption (l/kg)
Wetting/bleaching	
wetting of not sized fabric	3
rakojet+steamer(bleaching)	3.86
rinsing	5
neutralising	1
Total	12.86
Mercerising	
mercesering PES/CO	n.a.
rinsing PES/CO	n.a.
neutralising PES/CO	n.a.
TOTAL	10.38
Combined dyeing	
padding the dyestuff (HF1-2)	0.6
padding (PS 2)	n.a.
water seal	8
rinsing (PH:11.1)	4.5
rinsing (PH:10)	4.5
oxidising (PH:8.8)	1.3
oxidising (PH:10.7)	1.1
rinsing (PH:8.63)	1.6
neutralising (PH:4.4-T:50 C)	1.6
neutralising (PH:4.4-T:20 C)	1.6
TOTAL	24.8
Finishing	
WATER USE MAX	n.a.

Water consumption of general facilities is not available.

3.2.1.2 Electricity consumption

Annual electricity consumption of specific processes has been calculated as [absorbed power] x [working time/year] as summarised in Table 3.3.

Table 3.3 Electricity consumption

Department.	Equipment	Absorbed power ([kWh/month]	Working time	Absorbed power (kWh/yr)
pretreatment	pad-batch	10 kW per hour	1411 h/yr	14110
	rakojet	9 000	11 month/yr	99000
	mercerising line	12 605	11 month/yr	138655
dyeing	hot flue	2 708	11 month/yr	29788
	pad-steam	1 318	11 month/yr	14498
	pad-steam	13 500	11 month/yr	148500
	pad-batch	10 kW per hour	785 h/yr	7850

3.2.1.3 Methane consumption

Methane is consumed for steam production. 95% of methane is used for steam production necessary for heating water of industrial processes described in PIDACS. 5% is used for heating the factory shed (estimation of the company technicians).

There were no process specific data concerning steam consumption. PIDACS contains information about annual methane and steam consumptions. After consultation of expert of Centexbel, allocation to the reference flow of annual steam and methane was made on a mass basis. Table 3.4 shows the annual consumption of methane and steam, and the factors used for allocation.

Table 3.4 Values and factors used for calculation of process specific methane and steam consumption

	Unit	Value	Comment
methane consumption of B05	m^3/yr	7500000	
methane consumption for water heating	m^3/yr	7125000	95% of methane consumption in B05
steam consumption	m^3/year	50000	
factor “steam/methane”	m^3 / m^3	0.007	

3.2.1.4 Consumption of chemicals

Table 3.5 shows the concentration of chemicals used for each process. The mass of chemicals was calculated multiplying the concentration by the volume of consumed water (see Chapter 3.2.1.1) or the mass of treated fabric (when concentration is defined in ml of chemicals/kg fabric).

Table 3.5 Concentration of chemicals

	Formic acid	Detergent	H_2O_2(200% vol)	NaOH(50%)	Stabilishing agent	Vat dyestuff	antifoam agent(1/100)	sodiuhydrosulphite	Dispers dyestuff	Anti-migration agent	Acid acetic
	ml/l	ml/kg	ml/ kg	ml/ kg	ml/kg	g/l	ml/l	g/l	g/l	g/l	ml/l
Wetting-bleaching											
wetting of not sized fabric PES/CO											
rakojet+steamer (bleaching)		20	50	40	10						
neutralising	n.a..										
Mercerising											
mercerising				n.a.							
neutralising	n.a.										
Combined dyeing											
padding the dyestuff+drying on HF1-2						21	8		2.2	8	
padding				85				140			
oxidising			15								
oxidising			15								
neutralising											n.a.
neutralising											n.a.

3.2.1.5 Discharged water

Discharged flow rates were calculated considering that 12% of the consumed water (see Chapter 3.2.1.1) is evaporated. Annual COD emissions of processes were allocated to the referencee flow on a mass basis. Table 3.6 shows the COD concentrations of discharged waters.

Table 3.6 Discharged water

	litre water/kg fabric	**kg COD/yr**	**kg fabric /year**	**g COD / 100 kg fabric**
wetting-bleaching	11.3	97500	5696040	1712
mercerising	9.1	25000	4756500	525
combined dyeing	19.5	42194	14722680	286

3.2.2 Production of chemicals

Data about the production of chemicals were collected by a comprehensive review of the chemicals Life Cycle Inventories (LCI) available in commercial databases and softwares [6-11] and by direct contacts with the main textile chemicals manufacturers.In case of lack of data, production of chemicals was excluded from the product system.

In the Interpretation phase of the LCA study, a sensitivity check was made concerning the lack of data about production of chemicals. Surrogate inventory data about the production of organic chemicals [12] were used to evaluate the sensitivity of the product system (see

Chapter 5.2.2.2). Table 3.7 summarises the sources used for the production of each chemicals of the System.

Table 3.7 Production of chemicals

Name	Source
Formic acid	-
Detergent	-
H2O2 - 200% vol	TEAM
NaOH - 50%	TEAM
Stabilising agent	-
Vat dyestuff	-
Antifoamagent-1/100	-
Sodiumhydrosulphite	KCL-Eco
Oxidising agent	-
Dispers dyestuff	-
Antimigration agent	-
Acid acetic	TEAM

3.2.3 Energy production

Modules of TEAM 3.0 were used for the production processes of electrical and thermal energy. To calculate the emissions of methane burning and the natural resources consumption of the boiler, the TEAM 3.0 model was calibrated.
As Chapter 3.2.1.3 describes, the boiler of B05 consumes 1 m^3 of methane for the production of 0.007 m^3 steam. This amount of consumed methane corresponds to 32.54 MJ of energy input calculating with the next values:

- 0,72 kg/ m^3 is the density of the consumed methane,
- 1,13 kg methane extracted from the environment for supplying 1 kg combustible gas,
- 0,025 kg methane extracted from the environment for supplying 1 MJ consumable energy by combustion [6].

3.2.4 Waste water treatment plant (WWTP)

Table 3.8 summarize the data used to model WWTP.

Table 3.8 Data use for WWTP

	Units	Value
INPUT		
Wastewater	litre	8.87E+09
Electricity	MJ	2.90E+07
Transport: Road (diesel oil, kg.km)	kg.km	8.99E+08
OUPUT		
(w) Ammonia (NH4+, NH3, as N)	g	6.00E+07
(w) COD (Chemical Oxygen Demand)	g	5.19E+08
(w) Nitrates (NO3-)	g	7.89E+07
(w) Nitrites (NO2-)	g	1.77E+06
(w) Nitrogenous Matter (unspecified, as N)	g	1.40E+08

3.3 *Results of inventory analysis*

Results of the inventory analysis were preliminary evaluated with the impact assessment methods listed in Table 2.3. Significant flows - whose summed contribution is more than 99% for an impact category- were selected. Table 3.9 shows the values of these main flows.

Table 3.9 Results of inventory analysis of B05 cotton/polyester fabric system (only main flows are listed).

	Flow	Units	Value
INPUTS	(r) Iron (Fe, ore)	kg	4.52E-01
	(r) Natural Gas (in ground)	kg	9.43E+01
	(r) Oil (in ground)	kg	1.88E+00
	(r) Uranium (U, ore)	kg	4.07E-04
	PES/CO fabric	kg	1.00E+02
	Water: Treated	l	5.16E+03
	Water: Unspecified Origin	l	9.33E+04
OUTPUTS	(a) Alkane (unspecified)	g	1.08E+01
	(a) Aromatic Hydrocarbons (unspecified)	g	7.57E-01
	(a) Arsenic (As)	g	1.80E-03
	(a) Benzene (C6H6)	g	1.61E+00
	(a) Butane (n-C4H10)	g	3.22E+00
	(a) Carbon Dioxide (CO2, fossil)	g	2.44E+05
	(a) Ethane (C2H6)	g	1.28E+01
	(a) Ethylene (C2H4)	g	4.60E+01
	(a) Hydrocarbons (unspecified)	g	2.43E+00
	(a) Hydrogen Chloride (HCl)	g	4.89E+00
	(a) Hydrogen Sulphide (H2S)	g	1.49E+00
	(a) Manganese (Mn)	g	2.23E-02
	(a) Methane (CH4)	g	3.33E+02
	(a) Nickel (Ni)	g	3.41E-02
	(a) Nitrogen Oxides (NOx as NO2)	g	1.89E+02
	(a) Propane (C3H8)	g	3.86E+00
	(a) Sulphur Oxides (SOx as SO2)	g	1.76E+02
	(a) Vanadium (V)	g	1.22E-01
	(s) Arsenic (As)	g	7.71E-04
	(s) Chromium (Cr III, Cr VI)	g	9.65E-03
	(s) Zinc (Zn)	g	2.90E-02
	(w) Ammonia (NH4+, NH3, as N)	g	2.71E+01
	(w) Cadmium (Cd++)	g	1.73E-04
	(w) Chromium (Cr III)	g	2.03E-02
	(w) COD (Chemical Oxygen Demand)	g	2.49E+02
	(w) Nitrate (NO3-)	g	3.75E+01
	(w) Nitrogenous Matter (unspecified, as N)	g	6.31E+01
	(w) Oils (unspecified)	g	4.00E+00
	PES/CO fabric	kg	1.00E+02
REMINDERS	COD: to Waste Water Treatment Plant	kg	9.83E-01
	E Feedstock Energy	MJ	2.02E+01
	E Fuel Energy	MJ	4.14E+03
	E Non Renewable Energy	MJ	4.13E+03
	E Renewable Energy	MJ	2.56E+01
	E Total Primary Energy	MJ	4.16E+03
	Electricity	MJ elec	1.77E+02

4 Life cycle impact assessment

Classification and characterization were done on the basis of the impact assessment methods selected during scope definition of the study (see Chapter 2.2.8).

5 Life cycle interpretation

5.1 Identification of significant issues

In the following paragraphs the graphs of the selected impact assessment categories and inventory data are presented for the system to highlight significant issues. Contributions of processes and steam production into impact assessment results are visualised, too. If production of chemicals has a significant contribution, more detailed information is given. The main contaminant flows which contribute to each category are specified.

5.1.1 Water consumption

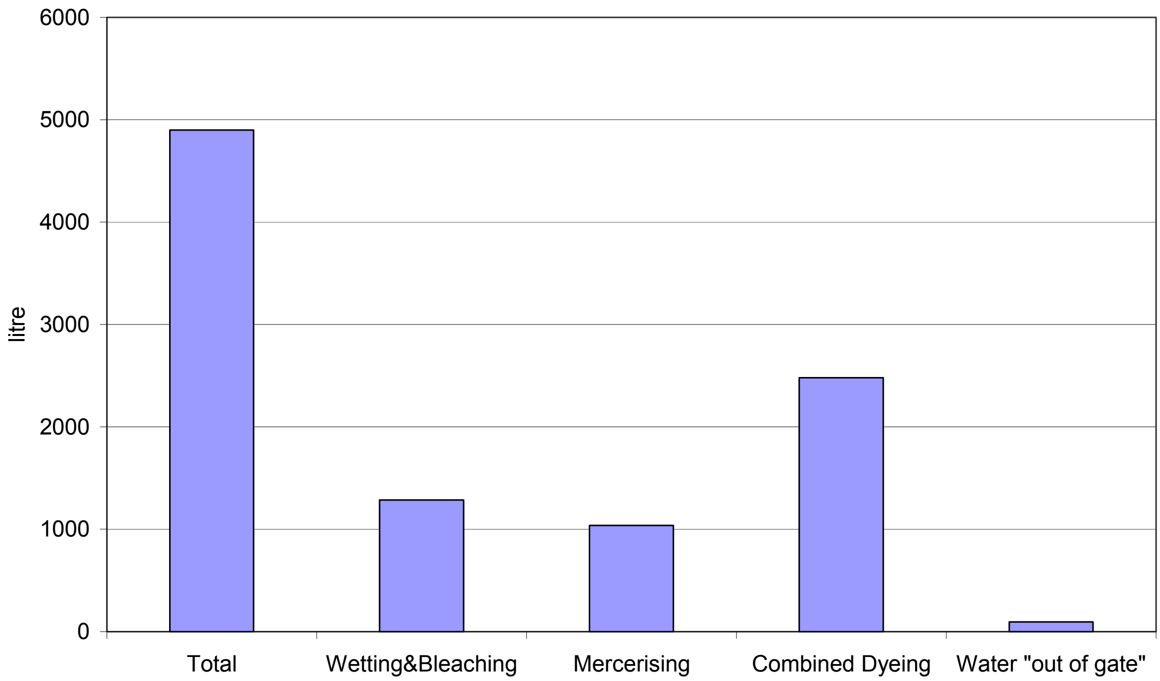


Figure 5.1 Water consumption

5.1.2 COD emissions

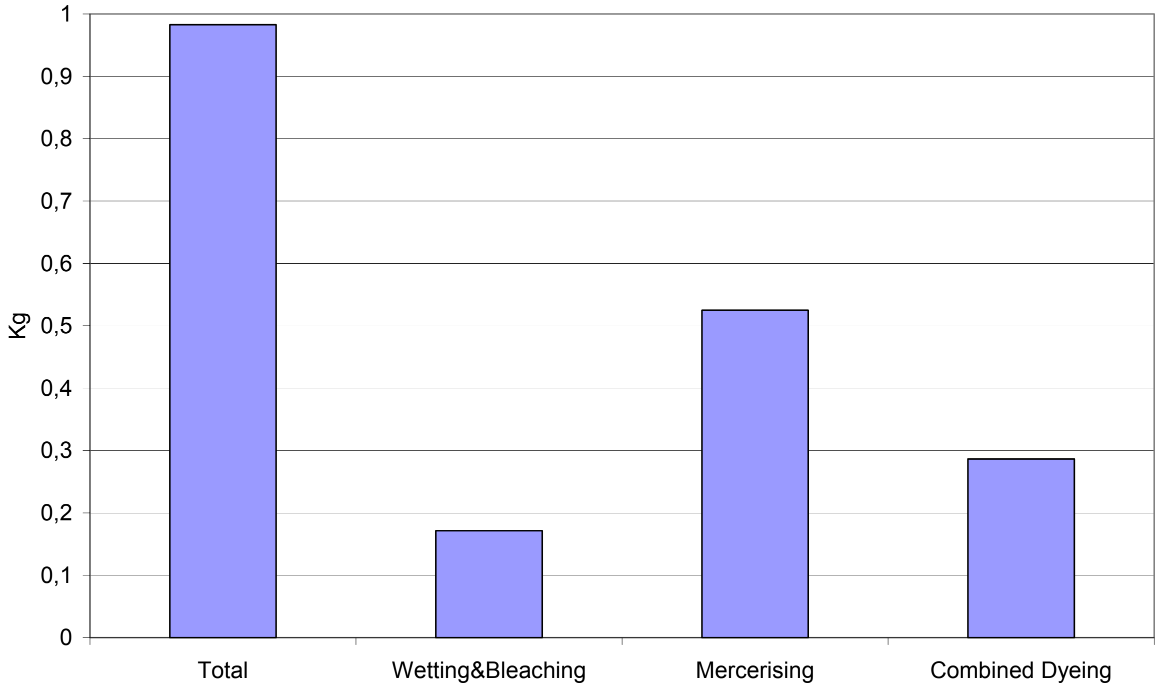


Figure 5.2 COD emission (to WWTP)

5.1.3 Energy indicators

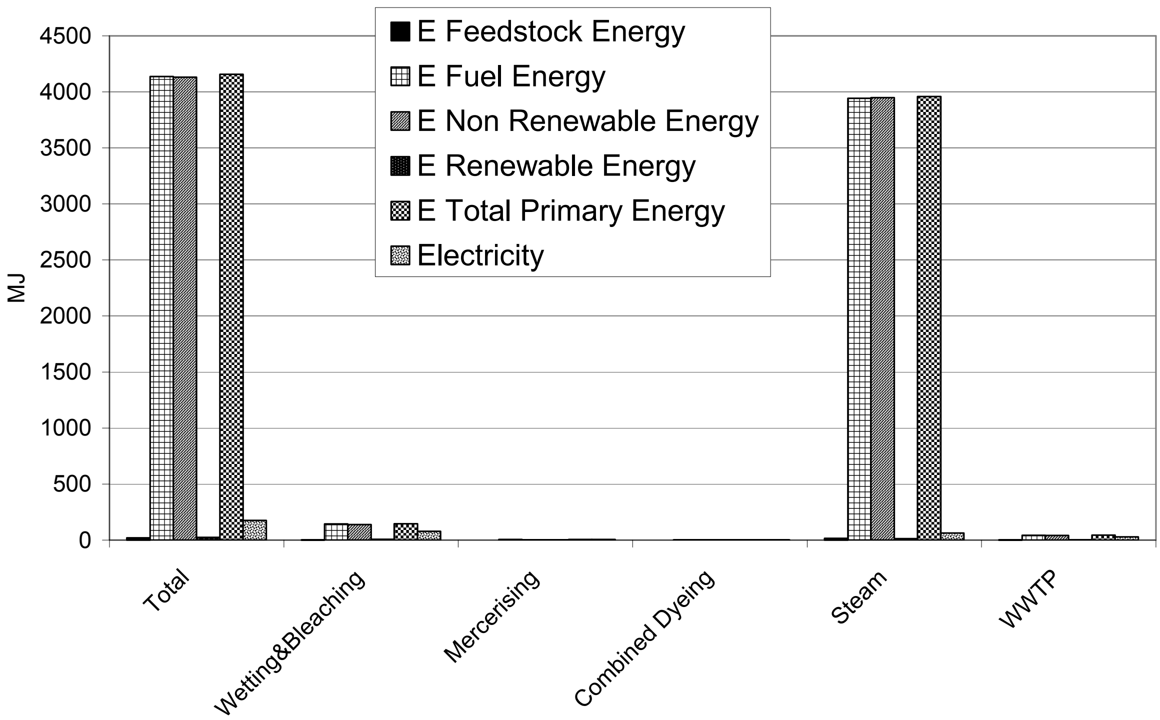


Figure 5.3 Energy indicators

5.1.4 Air Acidification

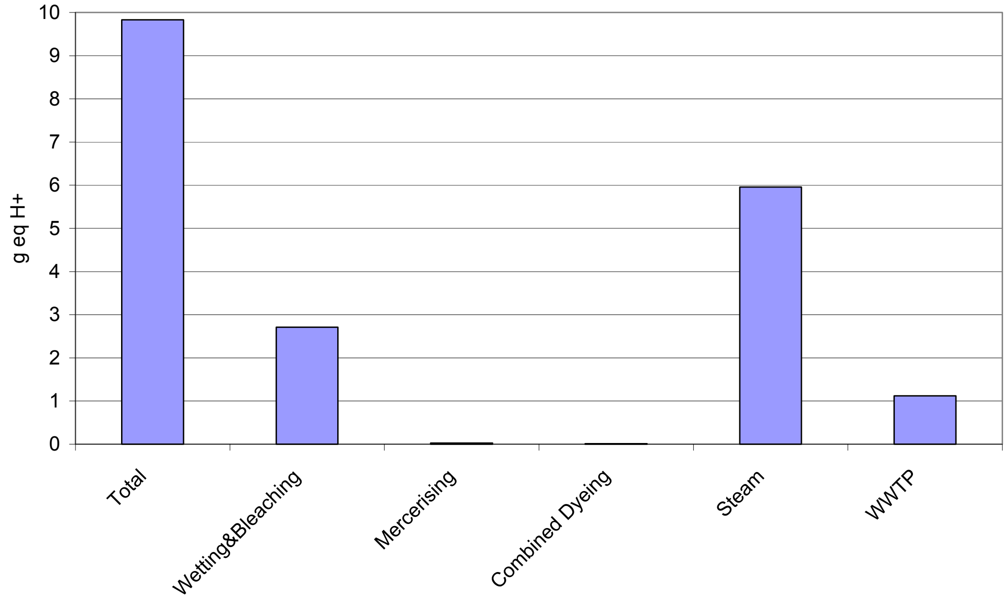


Figure 5.4 Air-Acidification

Wetting/bleaching process has significant contribution because of production of Hydrogen Peroxide and Sodium Hydroxide (their sum contributes for less than 3 g eq.H^+). The main airborne emissions which contribute to total value are sulphur oxides (56%) and nitrogen oxides (42%).

5.1.5 Aquatic ecotoxicity

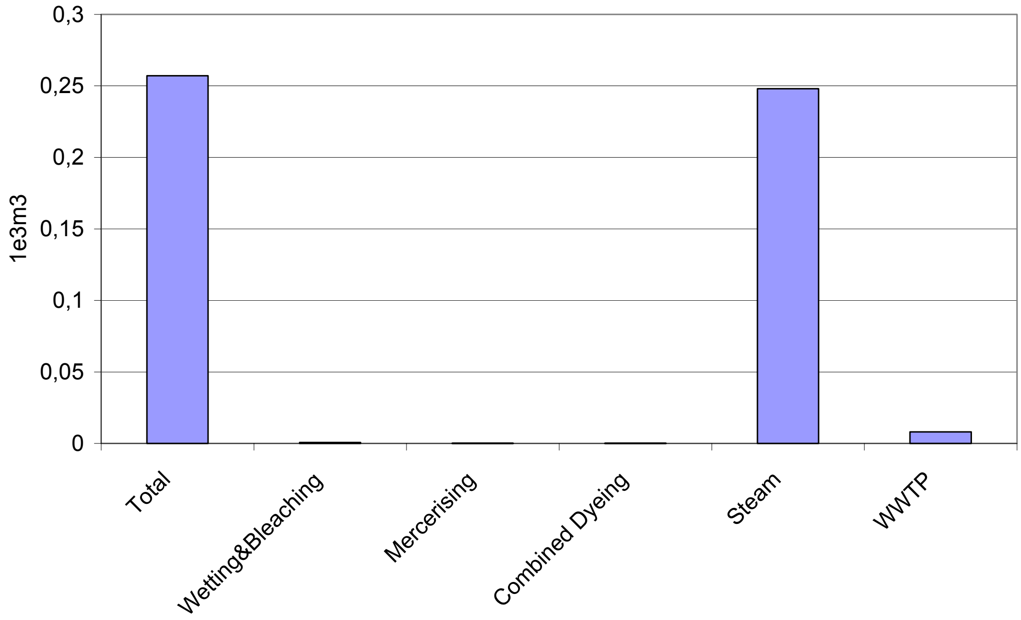


Figure 5.5 Aquatic ecotoxicity

Chemical production has not significant contribution: the production of Sodium Hydroxide in Wetting/Bleaching contributes for less than 0,5 m^3 of contaminated water. Mercerising and combined dyeing don't have any important contribution.

5.1.6 Depletion of non renewable resources

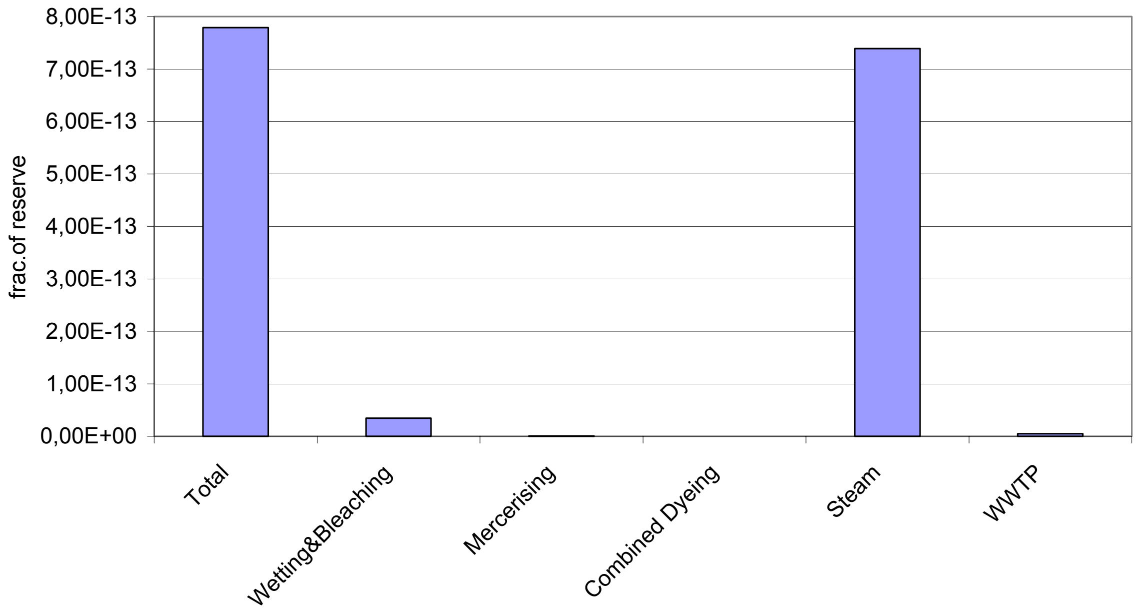


Figure 5.6 Depletion of non renewable resources

The main resource which contributes to total value is natural gas (93%).

5.1.7 Human toxicity

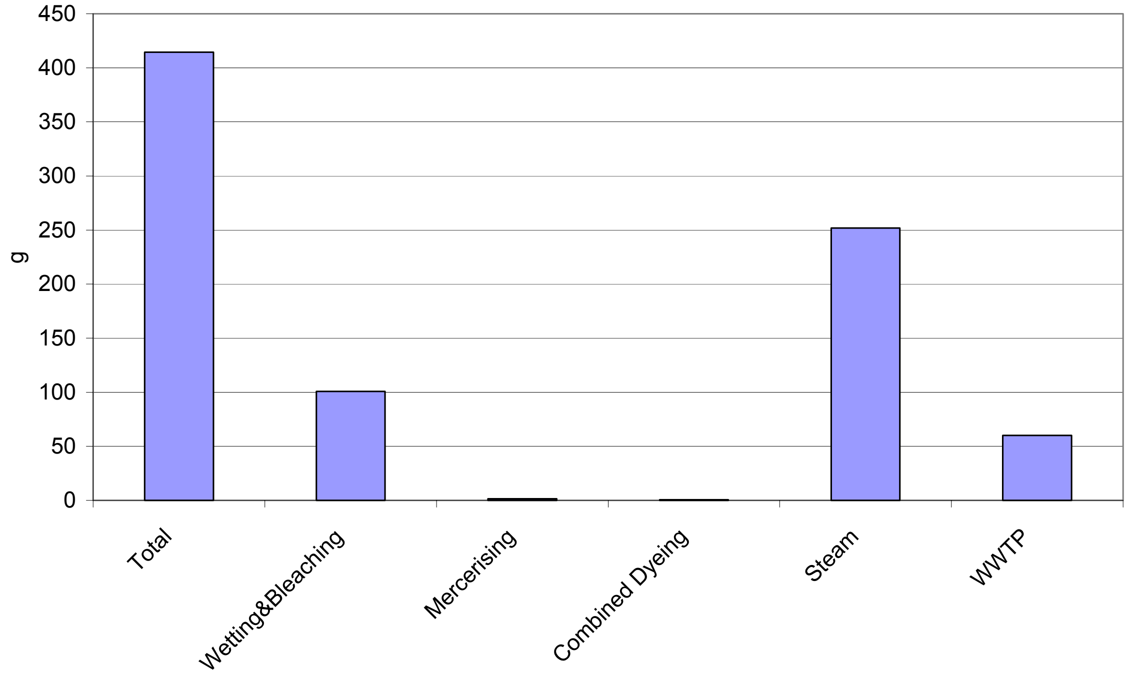


Figure 5.7 Human toxicity

Wetting/Bleaching has significant contribution because of the production of Hydrogene Peroxide (≅74g) and Sodium Hydroxide (≅ 26 g). WWTP has a big contribution (≅ 60 g) causing considerable airborne emissions: sulphur oxides (51%) and nitrogen oxides (36%).

5.1.8 Terrestrial ecotoxicity

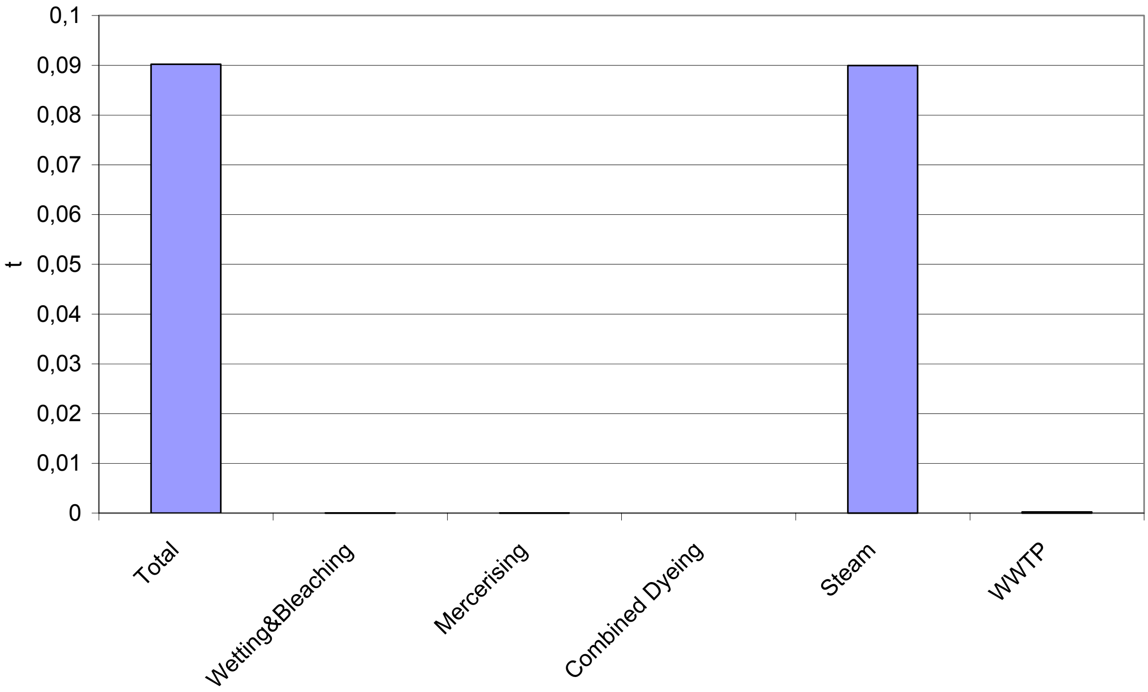


Figure 5.8 Terrestial ecotoxicity

The main soil emissions which contribute to total value are zinc (92%).

5.1.9 Eutrophication

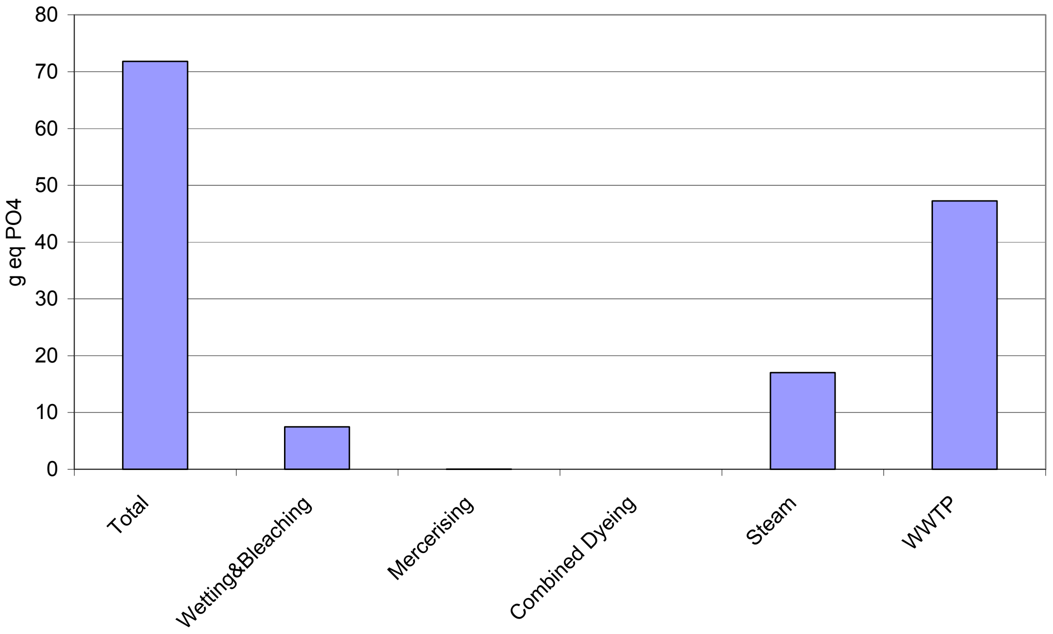


Figure 5.9 Eutrophication

Wetting/Bleaching has significant contribution because of the production of Hydrogen Peroxide (≅ 6 g eq. PO4). The main waterborne emissions which contribute to total value are nitrogen oxides (34%), nitrogenous matter (37%) and ammonia (16%).

5.1.10 Greenhouse effect

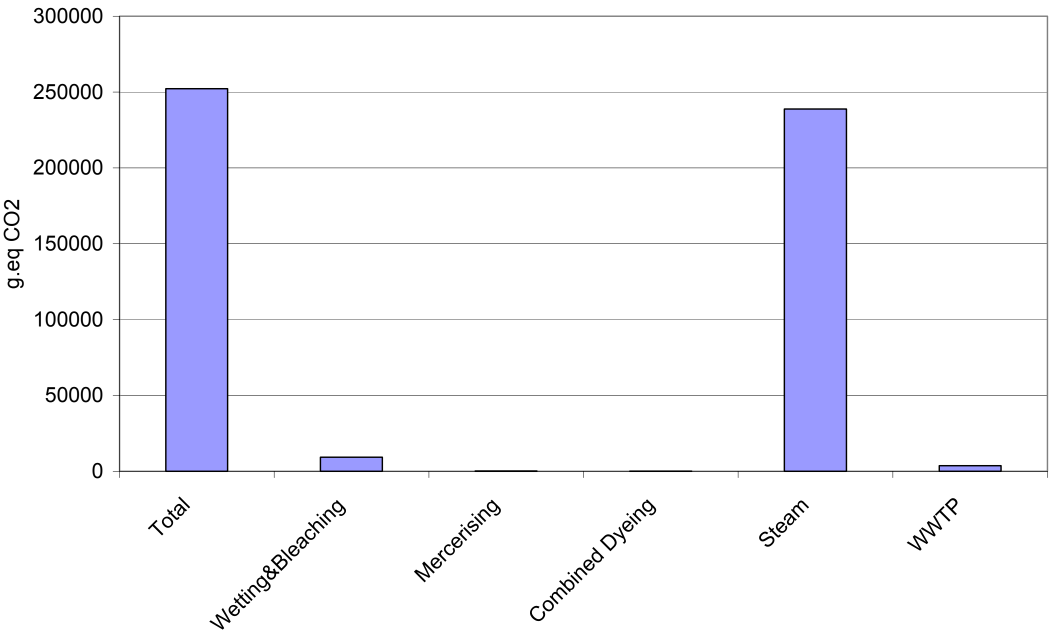


Figure 5.10 Greenhouse effect

The main airborne emission which contributes to total value is carbon dioxide (97%).

5.1.11 Photochemical smog

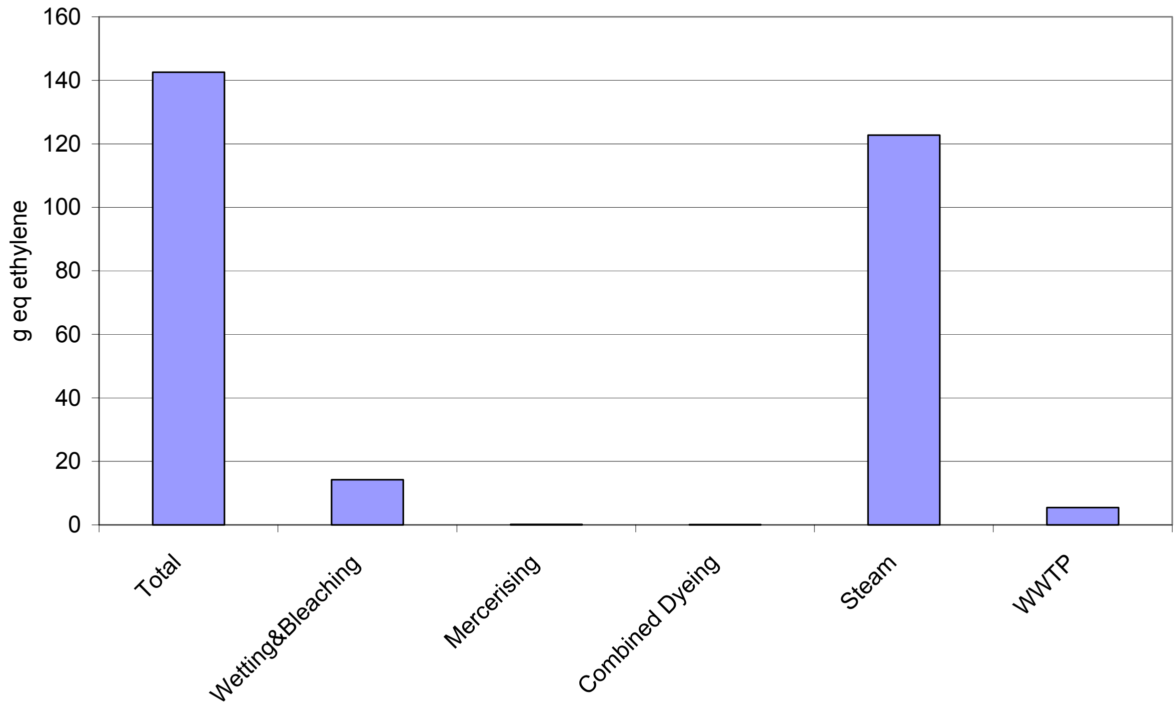


Figure 5.11 Photochemical oxidant formation

Wetting/Bleaching has significant contribution because of the production of Hydrogen Peroxide (≅12 g eq ethylene). The main airborne emissions which contribute to total value are hydrocarbons (40%) and ethylene (32%).

5.2 Evaluation

5.2.1 Completeness check

The LCA study cannot be considered complete because of several lack of data regarding:

- consumption and emission of finishing process
- concentration of some chemicals,
- TSS emissions of processes,
- solid waste,
- airborne emissions,
- transport of chemicals,
- production of numerous chemicals,
- general facilities.

5.2.2 Sensitivity check

5.2.2.1 Contribution analysis of steam

The allocation rule applied for the definition of steam and methane consumption (described in Chapter 3.2.1.3) is based on theoretic calculations and not direct measures. The final results of the study identified steam consumption as a significant issue for several inventory and impact categories. A contribution check was necessary to analyse the uncertainty of this assumption to the final results.

Table 5.1 shows the contribution of steam production into the impact categories. There are several categories in which steam production contributes for more than 40%. Because LCA methodology considers the relations among the system variables linear, a data uncertainty of 25% can cause 10% of deviation of the final results.

Table 5.1 Contribution of steam production to total results

	Contribution of steam production	Deviation of final results (25% of uncertainty)
Air Acidification	61%	15%
Aquatic Eco-toxicity	96%	24%
Depletion of non renewable resources	95%	24%
Eutrophication	24%	6%
Human Toxicity	61%	15%
Terrestrial Eco-toxicity	100%	25%
Greenhouse effect (direct, 100 years)	95%	24%
Photochemical oxidant formation (high)	86%	22%
Feedstock Energy	82%	21%
Fuel Energy	95%	24%
Non Renewable Energy	96%	24%
Renewable Energy	46%	12%
Total Primary Energy	95%	24%
Electricity	35%	9%

5.2.2.2 Lack of data about chemicals

The lack of data about the production of several chemicals can influence final results. To analyse the sensitivity of systems, surrogate inventory data on the production of organic and inorganic chemicals were used [2]. Table 5.2 shows the deviation of final results due to the application of these surrogate data.

Table 5.2 Deviation of total results because of lack of data on chemicals production

	Deviation
Air Acidification	15%
Aquatic Eco-toxicity	5%
Depletion non ren. resources	2%
Eutrophication	2%
Human Toxicity	18%
Terrestrial Eco-toxicity	0%
Greenhouse effect	3%
Photochem. Ox. formation	6%
Water	21%
Feedstock Energy	140%
Fuel Energy	3%
Non Renewable Energy	3%
Renewable Energy	37%
Total Primary Energy	4%
Electricity	30%

The system is very sensitive to the lack of data on chemicals for some energy indicators (feedstock energy, renewable energy, electricity). These energy categories have relatively low total values compared to other energy indicators (see Figure 5.3), so electricity and heat fuel oil consumption of organic chemicals production can influence significantly these results.

5.2.2.3 Consistency check

The LCA study can be considered consistent. Most of the data come from PIDACS or from TEAM 3.0 modules which guarantee a good general consistency. Processes having a different origin are the waste water power plant (Lariana Depur) and the production of sodium hydrosulfite (KCL Eco) which influence on the overall system is limited.

6 Conclusions

For the Life Cycle Assessment of cotton/polyester products of the B05 company the following main conclusions can be drawn:

- The product system requires 49 litre of water for 1 kg of product. Only a negligible amount is consumed out of the company gates. Water consumption of combined dyeing process is the highest (50%).
- Steam consumption was calculated applying an allocation rule based on mass. Production of steam has very significant contribution to each inventory- and impact assessment category (24%-100%). The product system is very sensitive for this issue: the uncertainty of the applied allocation principle can cause a considerable deviation of total values.
- Production of electricity is not a significant issue. Most of the electricity consumed in B05 company is related to a big weaving department that is outside the system boundaries of the LCA study. The analysed processes have relatively low electricity consumptions.
- Hydrogene Peroxide production (for wetting/bleaching) has significant contribution to acidification, human toxicity, photochemical smog and eutrophication.
- COD emissions arise from bleaching, mercerising and combined dyeing processes, but exact interpretation is not possible because of lack of data.
- It must be highlighted that the LCA study has a relevant lack of data on chemicals production. A sensitivity check, using surrogate data on organic and inorganic chemicals demonstrated the importance of this aspect: final results can have significant deviation because of this assumption (acidification (15%), human toxicity (18%), water (21%), electricity (30%), renewable energy (37%)).
- Hot-spot of eutrophication impact category is the waste water treatment plant because of its emissions to water (66% contribution of the total of category).

References

[1] ISO 14040 Environmental management - Life cycle assessment - Principles and framework, 1997.
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[14] IPPC Guideline for National Greenhouse Gas Inventories: Reference Manual, 1996.

Annex 1 : Structure and content of PIDACS

Company:
Date:

a) Production:

Reference year:

Fiber	*Type*	*processed kg*
TOTAL:		

Notes:

b) Water use:

Reference year:

b.1) Supplied water:

Source	*Quantity [m^3/yr]*	*Cost [€/m^3]*
TOTAL:		

Notes:

b.2) Process water and treatment for internal use:

Water type	*Source*	*Treatment*	*Use*	*Quantity [m^3/yr]*	*Treatment specific cost [€/m^3]*

Notes:

b.3) Process water analytic features:

Source-Type		
T [°C]		
Conductivity [mS/cm]		
Hardness [°F]		
pH [-]		
COD [mg/l]		

TSS [mg/l]		
Fe (mg/l)		
Mn (mg/l)		
- - - - -		

Notes:

b.4) Steam production:

Source-Type	*Quantity [m^3/yr]*	*T max [°C]*	*Use*

Notes:

b.5) Discharged water:

Type		
Quantity [m^3/yr]		
Final destination		
Features:		
T [°C]		
Conductivity [mS/cm]		
Hardness [°F]		
pH [-]		
COD [mg/l]		
BOD5 [mg/l]		
SST [mg/l]		
***Total N** [mg/l]*		
N-NH4 [mg/l]		
N-NO2 [mg/l]		
N-NO3 [mg/l]		
Ptot [mg/l]		
Absorbance 420 nm		
Absorbance 550 nm		
Absorbance 680 nm		
Anionic surf. [mgMBAS/l]		
Non-ionic surf. [mgBiAS/l]		
Cationic surf. [mg/ l]		
Chlorides [mg/l]		
Chlorine [mg/l]		
AOX [mg/l]		
Chrome [mg/l]		
Copper [mg/l]		
Endocrine activity		
Hydrocarbons [mg/l]		
Iron [mg/l]		
Manganese [mg/l]		

Nickel [mg/l]		
Zinc [mg/l]ì		
Toxic Units (for algae)		
Toxic Units (for fish)		
Toxic Units (for bacteria)		
Toxic Units (for invertebrates)		

Notes:

c) ENERGY CONSUMPTIONS:

Source	*Unit*	*Use*	*Quantity*	*Specific cost [€/]*

Notes:

d) DEPARTMENTS AND WORKING TIME:

Department.	*Operating days*	*Daily operating period*	*Weekly operating period*	*N° of shifts per days*

Notes:

e) EQUIPMENT:

Department.	*Equipment*	*Item*	*Quantity*	*Operating*	*Bath Volume $[m^3]$**

Notes:

ANNEXES (***all sheets have to be considered as relevant part of the whole document***):

- **An.1**: ***Material flow chart***;
- **An.2:** ***Energetic flow chart***;
- **An.3**: ***Water flow chart;***
- **An.4**: ***Production model;***
- **An.5**: ***Preparation, Dyeing, Finishing - Process scheme;***
- **An.6:** ***Water consumptions;***

An.7: ***Water discharges;***