TOWEF0

(Toward Effluent Zero)

EVALUATION OF THE EFFECT OF THE IPPC APPLICATION ON THE SUSTAINABLE WASTE MANAGEMENT IN TEXTILE INDUSTRIES

IDENTIFICATION CODE:	DIS.:	PAG.:	OF PAG.:
TM-108-006	PU	1	48

PARTNER:	WORKPACKAGE:
ENEA	WP08

EXTERNAL IDENTIFICATION CODE:

CONTRACT NUMBER:

EVK1-CT-2000-00063

TITLE:

Life Cycle Assessment of silk fabric in I15 company

KEY WORDS:

LCA

ANNOTATIONS:

*Authors:
B. Sára, S. Di Giovannantonio FEBE EcoLogic
M. Tarantini ENEA

FEBE EcoLogic

Studio Associato di Consulenza e
Formazione Ambientale
“Sára Balázs & Associati”
Via Canalazzo, 44
48100 Ravenna - Italia
Tel. & Fax. +39-0544-465722
www.febe-ecologic.it
info@febe-ecologic.it

0	15.02.04	Emission	B. Sára*	D. Mattioli	D. Mattioli
REV.	DATE	DESCRIPTION	EDITING	VALIDATION	APPROVAL

PERIOD COVERED BY REPORT	SECTIONS INCLUDED:	CO-ORDINATOR NAME:	PROJECT HOME PAGE:

Contents

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 silk fabric products within I15 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 I15 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, an ENEA contractor. 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

I15 is an Italian company located in the Como area. Its annual production is over 2801 tons of textile products mainly made of silk fabric (59%), synthetic fibre (17%), PES (14%) and natural fibre (10%). The general organization of the company production departments is highlighted in the following material flowchart.

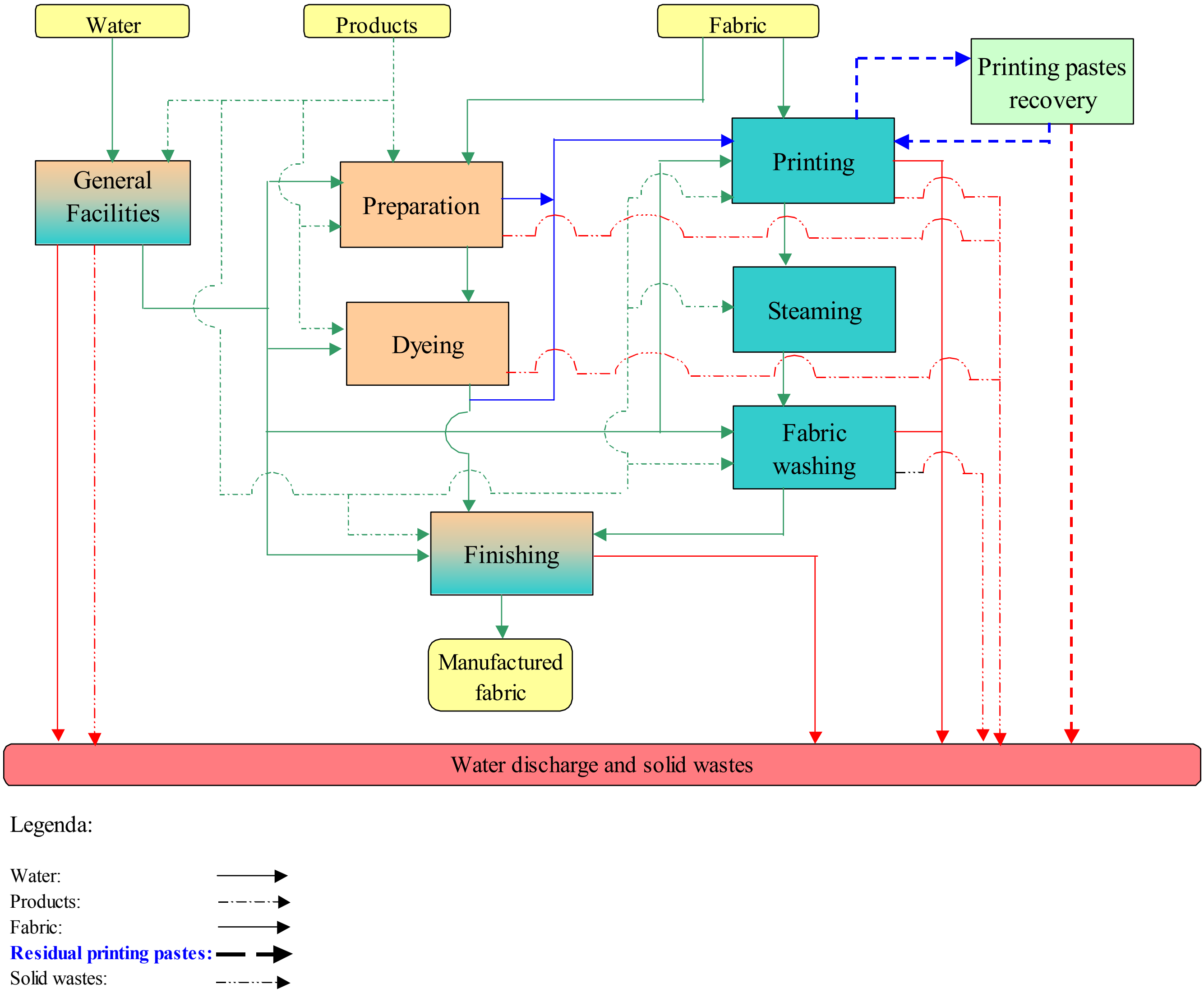

Fig. 2.1 Material flowchart of I15 company

A more detailed description of I15 company is available in the Process Identification and data Collection Sheet (PIDACS) of the company.
In this study two product alternatives were analysed:

- silk fabric produced through acid dyeing (System A);
- silk fabric produced through acid printing (System B).

The general flow-chart of the two systems is shown in Fig 2.2

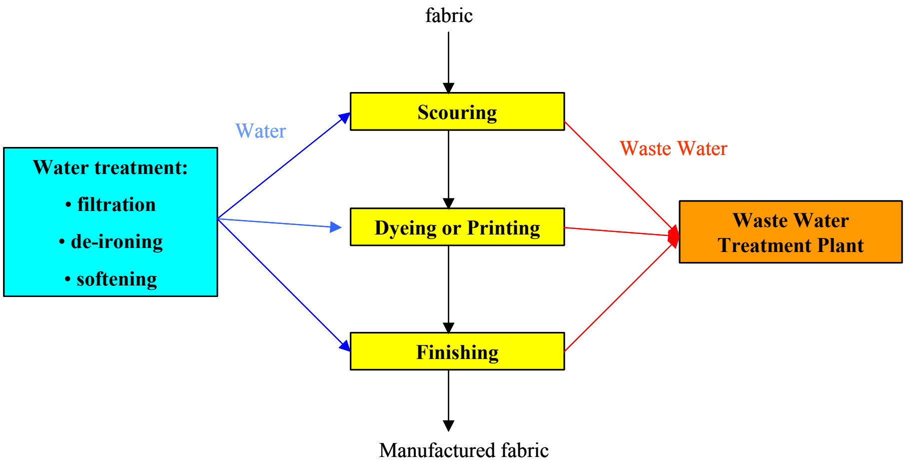

Fig.2.2 Schematic flowchart of analysed silk fabric products

Table 2.1 shows the textile wet processes of the two product systems; the process numbers refer to I15 PIDACS classification.

Product systems	**System A**	**System B**
Preparation		
Silk continuous scouring	F.1.1.	F 1.1.
Dyeing		
Silk dark acid dyeing	G.3.1.	-
Printing		
Acid blender preparation	-	H 1.1.
Acid colours preparation	-	H 2.1.
Acid colours thickeners preparation	-	H 3.1.
Acid printing paste preparation	-	H 4.1.
Flat table acid printing	-	H 5.2.
Printing screen washing	-	H 8
Kids washing	-	H 10
Saturated steaming	-	I 2.1.
Acid printed washing	-	L 2.1.
Finishing		
Morbidol finishing	M 3.4.	M 3.4

Table 2.1 Textile processes of the product systems

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].

Silk
Silk is derived from the silk worm, which spins a cocoon around itself. It is a protein fibre like wool and it is the only natural filament fibre to be used with success in the textile industry (the length of the thread is in the range of 700 to 1550 m). The silk fibre is composed of fibroin filaments wrapped with sericine (silk gum), which has to be removed during the pretreatment.

Scouring
Scouring (also known as boiling-off or kier boiling) is aimed at the extraction of impurities present on the raw fibre or picked up at a later stage.
Scouring can be carried out as a separate step of the process or in combination with other treatments (usually bleaching or desizing) on all kind of substrates: woven fabric (sized or

desized), knitted fabric and yarn. Woven fabric is scoured in continuous mode using the pad-steam process.
To prepare silk fabric for dyeing or printing, it is necessary to partially or completely remove sericin, as well as natural oils and organic impurities. Depending on the percentage of sericin removed during scouring, the end-product is defined as unscoured (use only for shirts and suits), “souple” or degummed.
The scouring treatment can be carried out in a neutral, acid or alkaline solution, depending on the desired results. At the industrial level, treatment in alkaline conditions (sodium hydroxide or sodium carbonate) together with auxiliaries (non-ionic and anionic surfactants,, complexing agents, polyacrylates and phosphonates as special surfactant-free dispersing agents, sulphite and hydrosulphite as reducing agents) is by far the most common. It is extremely important to control the temperature.

Acid dyeing
Silk is dyed with the same dyes as wool. In addition, direct dyes can be used. The dyeing pH is slightly higher than with wool.
Acid dyes are typically applied in acidic conditions, but the used pH range used varies depending on the type of acid dye. The greater the affinity of the dyestuff for the fibre, the more the hydrophobic interaction must be repressed by applying the dye at higher pH:

- level-dyeing colorants are applied under strongly acidic conditions in the presence of sulphate ions to assist migration and levelling;
- fast acid dyes exhibit superior fastness properties, while retaining some of the migration properties;
- acid milling dyes have good affinity for the fibre and do not migrate well at the boil.

Levelling agents play an important role in acid dyeing. A number of non-ionic, cationic, anionic and amphoteric surfactants belong to this category.

Printing
Printing, like dyeing, is a process for applying colour to a substrate. However, instead of colouring the whole substrate (cloth, carpets of yarn) as in dyeing, printing colour is applied only to defined areas to obtain the desired pattern. This involves different techniques and different machinery with respect to dyeing, but the physical and chemical processes that take place between the dye and the fibre are analogous to dyeing. Moreover, a distinction should be made between printing with pigments, which have no affinity for the fibre, and printing with dyes (reactive, vat, disperse, etc.).
A typical printing process involves the following steps:

- colour paste preparation: when printing textiles, the dye or pigment is not in an aqueous liquor, instead, it is usually finely dispersed in a printing paste, in high concentration;
- printing: the dye or pigment paste is applied to the substrate using different techniques;
- fixation: immediately after printing, the fabric is dried and then the prints are fixed mainly with steam or hot air (for pigments);
- after-treatment: this final operation consists in washing and drying the fabric.

Finishing
The term “finishing” covers all those treatments that serve to impart to the textile the desired end-use properties. These can include properties related to visual effect, handle and special characteristics such as waterproofing and non flammability. Finishing may involve

mechanical/physical and chemical treatments. Moreover, among chemical treatments one can further distinguish between treatments that involve a chemical reaction of the finishing agent with the fibre and chemical treatments where this is not necessary (e.g. softening treatments). The application of softening agents does not involve curing processes.
The wastewater treatment for all the analysed Italian companies is performed in a centralised WWTP which treats also municipal effluents.
A detailed description of the studied systems is available in chapter 3.2.
A general description of the equipment 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 preparation, dyeing or printing and finishing of silk fabric, processed to reach the required commercial characteristics respecting the worker safety and the emission limits according to the law in air, water and soil.

2.2.3 Functional unit and reference flow

The chosen functional unit is the preparation, dyeing or printing and finishing of a weight unit of silk fabric, processed to reach the required commercial characteristics, respecting the worker safety and the emission limits according to the law in air, water and soil.
The reference flow is 100 kg of silk fabric.

2.2.4 System boundaries of product system

The system boundaries of the two studied product alternatives are shown in Fig. 2.3. The processes included in the analysis are included in the system bold line.

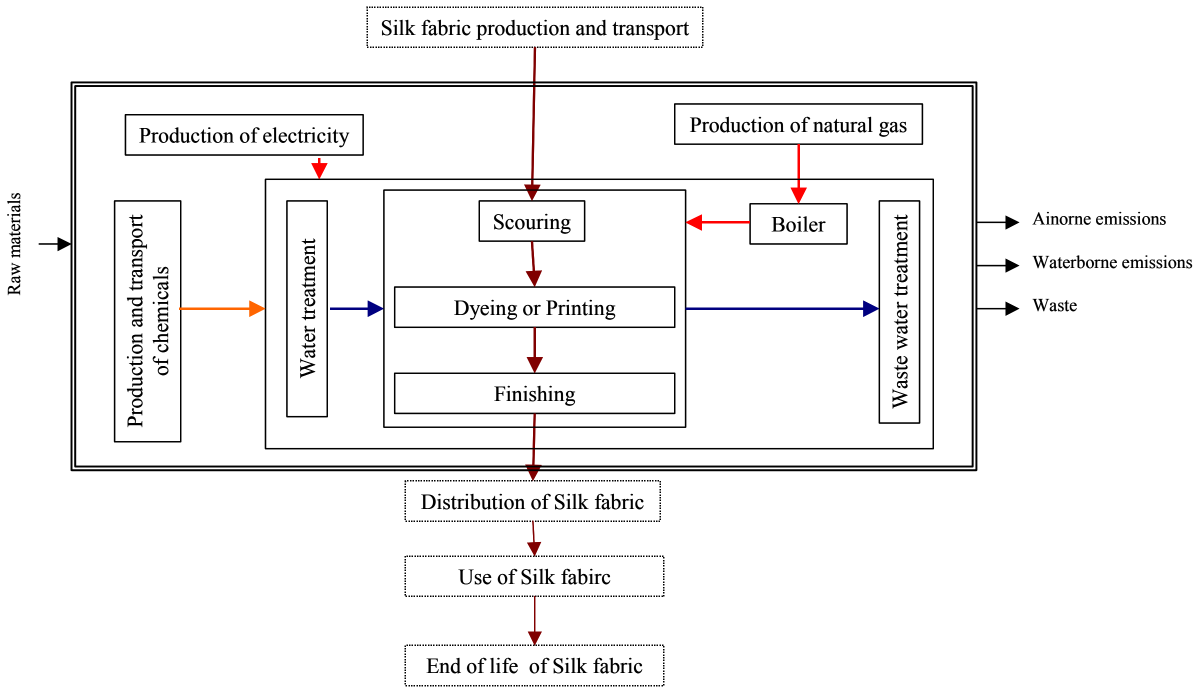

Fig 2.3 System boundaries of I15 product systems

The processes excluded from the system boundaries are:

- silk fabric production processes, including the relative transports;
- all the product life cycle phases external to the company gate;

- the production and manufacturing of all equipment, machinery 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 characterisation 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:

- Continuous scouring
- Dark acid dyeing
- Acid blender preparation
- Acid colours preparation
- Acid colours thickeners preparation
- Acid printing paste preparation
- Flat table acid printing
- Printing screen washing
- Kids washing
- Saturated steaming
- Acid printed washing
- Morbidol softener finishing
- Water treatment (rapid filtration, de-ironing, softening)

TEAM 3.0/Ecobilan data:

- production of electricity;
- production of methane;
- transport processes;
- boiler: general model whose process parameters and efficiency are adjusted to I15 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. Chemicals were treated as flows and characterised in the impact assessment (see Chapter 2.2.8). In the Interpretation phase of the LCA study, a sensitivity check was made on the lack of data about production of chemicals. Surrogate inventory data about the production of organic and inorganic 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 I15 data are related to year 2001;
- Geographical related coverage: the data are company specific and reflect the Como area situation.

To model the two product systems several assumptions were necessary:

Main assumptions within the company boundary:

- Steam production

The annual company methane consumption as well as the annual steam consumption are measured and reported on the I15 PIDACS. The 95% of the methane is used for industrial processes described in the PIDACS, the remaining part is used for heating the factory shed (estimation of the company technicians). To evaluate the specific methane consumption of scouring, dyeing and printing processes, the specific consumption of steam has been calculated (m^3 of steam/kJoule of required heating energy). The calculation of “required heating energy” took in account the volume of water to be heated, the bath temperature and the inlet water temperature. To evaluate the specific methane consumption of thermosetting in finishing processes, steam consumption has been calculated on the basis of the textile production (kg steam/kg silk fabric). To calculate the emissions of methane burning and the natural resources consumption, the TEAM 3.0 model developed by Ecobilan was used, adjusting the water inlet and the steam outlet temperatures on the actual company data and calibrating the steam generator efficiency.

- Process specific wastewater effluent

The wastewater effluent from the company specific processes has been characterised only with measured COD and TSS concentration, due to unavailability of specific contaminant concentration in wastewater analyses.

- Electricity consumption

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.

- Solid waste

The annual solid waste production of the company is specified in the PIDACS. The total waste quantity has been allocated to the analysed product systems on a mass basis. The solid waste treatment has not been included in the systems, because of lack of specific data and the difficulty to identify reference treatment scenarios.

- Airborne emissions.

PIDACS specifies for each emission source, typically a specific equipment, the chimney flow rate and the contaminant concentration. For LCA purposes the contaminant emissions in the environment have been calculated as: [emission source flow rate]x[equipment run time]x [contaminant concentration]. If the concentration has been indicated as < limit value, an average of the specific limit value has been assumed.

Main assumptions for production of chemicals:
The inventories available in the 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 the results of previous LCA studies of ENEA [13].
The potential environmental impacts for treating the waste water of the studied product systems have been considered proportional to effluent mass.
Direct greenhouse gas emissions to 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 contained in the effluents of the selected silk treatment processes, 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 analysed processes and the contaminant concentration of the treated WWTP effluent.

2.2.8 Impact assessment methods

The impact categories used for the analysis of the product systems are indicated in table.2.2

Table 2.2 Impact assessment categories

Category	Unit
CML 92-Air Acidification	g equivalent H+
CML 92-Aquatic Eco-toxicity	1000 m^3
CML 92-Depletion of non renewable resources	fraction of reserve
CML 92-Eutrophication	equivalent g PO4
CML 92-Human Toxicity	g
CML 92-Terrestrial Eco-toxicity	t
IPCC-Greenhouse effect (direct, 100 years)	equivalent g CO^2
WMO-Photochemical oxidant formation (high)	equivalent g 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.
Because of project limits (detailed analyses of process wastewaters were not available) and methodological limits (characterisation factors are available only for a small part of the manufactured chemicals), the EDIP (Environmental Design of Industrial Products method

proposed by Wenzel and Hauschild has been adopted for screening the potential impact of chemicals on ecotoxicity. A short description of the method is reported hereafter.
This EDIP screening method is based on the existing EU hazard classification of substances, available in the list of hazardous substances published by the EEC (1994). A semi-quantitative scoring of the substance in the inventory is obtained by calculating a score for exposure and a score for ecotoxicity, which are multiplied to give a final ecotoxicological impact score.
The idea behind multiplication of separate scores for exposure and ecotoxicity is that if emission of a substances is expected or if undesirable long term effects are possible, and the substance has some form of ecotoxicity, the score for environmental hazardousness will be increased significantly more than by simple addition. This is in agreement with a toxic property being assessed as having a greater environmental significance if the substance is emitted often, is not easily degradable or can undergo bioaccumulation.

Exposure score
The score for the exposure is a combination of expectation concerning emission (yes/no) and the possibility of undesirable long term effects on the environment (R53 or R58).
The two scores are added and their sum is multiplied by the score for ecotoxicity.
R53 is a classification assigned to substances which are not easily biodegradable or which are potential bioaccumulators, and where the following values are found for acute toxicity:
96-hour LC_{50} (fish)≤ 10 mg/l, or
48-hour EC_{50} (Daphnia))≤ 10 mg/l, or
72-hour IC_{50} (algae) 10 mg/l.
There are no criteria for assignment of an R58 classification, which refers to undesirable long term effects in environments other than the aquatic environment.

Ecotoxicity score
The score of ecotoxic effects is a combination of ecotoxicity to aquatic organisms(?) (R50-R51-R52 alone or in combination with other R phrases) and ecotoxicity to soil-dwelling organisms(?) (R54-R55-R54 R56-R57 alone or in combination with other R phrases). The two scores are added to give a total score for the substance's ecotoxicity (see table 2.3)

Tab. 2.3 Ecotoxicity scores

Aquatic ecotoxicity		**Terrestrial ecotoxicity**	
(**R50**….) $LC_{50} \leq 1$ mg/l	**4**	**R54** Toxic to flora or	**4**
(**R51**….) 1mg/l< $LC_{50} \leq 10$ mg/l	**2**	**R55** Toxic to fauna or	
(**R52**….) 10 mg/l< $LC_{50} \leq 100$ mg/l	**1**	**R56** Toxic to soil organisms or **R57** Toxic to bees	

If no ecotoxicity data are available for the substance, it is assigned an ecotoxicity score of 8 (4 for water compartment and 4 for the soil compartment); if the substance is, however, well know and considered to have no significant hazardous effects, it is assigned a score of 0.

Ecotoxicological impact score

The total ecotoxicological impact score for the emissions is calculated by multiplying the score for exposure and the score for ecotoxicity as shown in table 2.4.

Tab. 2.4 Impact assessment categories

	Ecotoxicity score 0	Ecotoxicity score 1	Ecotoxicity score 4	Ecotoxicity score 8
No emission and not classified as R53 or R58 (score 1)	0	1	4	8
Emission expected or R53 or R58 (score 4)	0	4	16	32
Emission expected and R53 or R58 (score 8)	0	8	32	64

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 has been focused on allocation rules (thermal energy) and lack of inventory data for chemicals.

A comparison of the different product systems has been performed.

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 Qualitative and quantitative description of unit processes

The next paragraphs describe data collected for the inventory analysis. Data elaboration procedures are explained and assumptions and allocation procedures are documented.

3.2 Qualitative and quantitative description of unit processes

The next paragraphs describe data collected for the inventory analysis. Data elaboration procedures are explained and assumptions and allocation procedures are documented.

3.2.1 Silk wet processing and general facilities

Annex 1 describes general structure and content of the PIDACS.
In cooperation with Lariana Depur, the most representative production lines were identified and depicted in flow-charts of Figure 3.1.

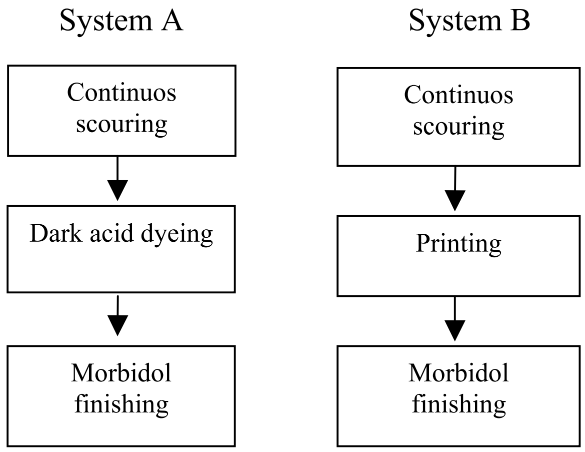

Figure 3.1 Flow-chart of the selected production lines

The most productive equipments were identified for each process of the selected production lines:

- **Z2** for silk continuous scouring : **1027044 Kg/yr**;
- **B1**(boat) for silk yarn dark acid dyeing : **60803 Kg/yr**;
- **BP** (blender preparator) for acid blender preparation: **503971 kg/yr;**
- **CP** (colour preparator) for acid colours preparation: **503971 kg/yr;**
- **TP** (thickeners preparator) for acid colours thickeners preparation: **503971 kg/yr;**
- **M** (mixer) for acid printing paste preparation: **503971 kg/yr;**
- **FT1** (flat table) for flat table acid printing: **122014 Kg/yr**;
- **WSC** (screen washer) for printing screen washing: **884192Kg/yr**;
- **KW** (kids washing) for kids washing: **884192 Kg/yr**;
- **S1** (steamer) for acid printing saturated steaming: **251896 Kg/yr;**
- **CW2** (continuous washer) for acid printed washing: **251896 Kg/yr**;
- **R1** (rameuse) for morbidol softener finishing: **193090 Kg/yr.**

Table 3.1 summarizes the processes where the selection of machineries were necessary on the basis of their percentage contribution to silk fabric production.

Table 3.1: Selection of equipments on the basis of annual production

	Silk dark acid dyeing	Flat table acid printing	Acid printed saturated steaming	Softener Finishing
annual production (ton)	121606	406714	503792	579270
Equipment				
B1	**50%**			
B2	35%			
B3	15%			
FT1		**30%**		
FT2		30%		
FT3		20%		
FT4		20%		
ST1			**50%**	
ST2			50%	
R1				**33%**
R2				33%
R3				33%

Specific data of the selected equipments and related processes were extracted from the PIDACS.
Processes of general facilities were analysed, too. Data were collected and elaborated for the next facilities:

- rapid filtration of water: **351380 m^3 water/year** capacity;
- de-ironing: **224004 m^3 water/year** capacity;
- storage of water: **575384 m^3 water/year** capacity;
- softening of water: **155929 m^3 water/year** capacity;

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 of the selected equipment.

3.2.1.1 Water use

Processes consume two types of water: “W3” is a mix of de-ironed well water and rapid filtered industrial water. “W4” is produced by softening of “W3”.
Table 3.2 shows the water consumption of the selected processes and equipments.

Table 3.2 Water consumption of textile treatment processes

	Water type	Water consumption (m^3/year)
Silk continuous scouring		
scouring	W4	3705
reintegration	W4	371
refreshing water	W4	3705
ammonia treatment	W4	20378
1st rinsing	W4	20378

	Water type	Water consumption (m^3/year)
2nd rinsing	W4	20378
Silk dark acid dyeing		
dyeing bath	W4	253
1st rinsing	W4	253
2nd rinsing	W3	253
filling	W3	253
Acid blender preparation		
mixing	W4	425
washing	W3	883
Acid colour preparation		
mixing	W4	1
washing	W3	441
Acid colour thickeners preparation		
mixing	W4	4
washing	W3	44
Acid printing paste preparation		
washing	W3	57692
Flat table acid printing		
table washing	W3	452
Printing screen washing		
washing	W3	72331
rinsing	W3	72331
Kids washing		
1st rinsing	W3	4018
2nd rinsing	W3	4018
3rd rinsing	W3	4018
4th rinsing	W3	4018
Acid printed saturated steaming		
washing	W4	318
Acid printed washing		
doping bath	W4	210
reintegration	W4	252
1st bath	W4	210
2nd bath	W4	210
1st rinsing	W4	210
3rd bath	W4	210
2nd rinsing	W3	210
3rd rinsing	W3	210
Morbidol softener finishing		
filling	W4	38
doping	W4	193
Rapid filtration of water		
backwashing	W1	793
rinsing	W1	317
De-ironing		
backwashing	W3	17
regeneration	W3	26
rinsing	W3	9
Softening		
backwashing	W3	159
regeneration	W3	239
rinsing	W3	80

3.2.1.2 Electricity consumptions

Table 3.3 describes the electricity consumption of each item for every process.

Table 3.3 Consumption of electricity

	item	absorbed power (kW)	working hours/year	electricity (kWh/year)
Silk continuous scouring	Z2	21.5	6801.6	146234
Silk dark acid dyeing	B1	2.3	1140	2622
Acid blender preparation (*)	BP	18.0	3268.3	58830
Acid colour preparation (*)	CP	4.5	981	4415
Acid colour thickeners preparation (*)	TP	4.5	1.63	7.35
Acid printing paste preparation (*)	M	4.5	2136.7	9615
Flat table acid printing	FT1	2.7	4519	12201
Printing screen washing (*)	WSC	2.7	2679	7233
Kids washing (*)	KW	11.0	6697.5	73673
Saturated steaming	ST1	9.7	1167	11312
Acid printed washing	CW2	13.5	833	22671
Morbidol softener finishing	R1	29.6	1073	31752
GENERAL FACILITIES				
De-ironing	DI1	28.0	5352	149856
Softening	S1	8.0	5352	42816
Demineralising	DM1	24.0	5352	128448
Steam production	TS1	32.0	5352	171264

(*) no available data on yearly working hours of items; calculation of working ours has been done considering [run time] x [number of run/yr].

3.2.1.3 Methane consumption

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

PIDACS contains information about annual methane and steam consumptions.
Specific steam consumption for thermosetting in finishing processes has been estimated as 1 kg steam/1 kg textile by process experts of Lariana Depur. Allocation of annual steam and methane consumption for other processes was made by energy calculated with the next formula:

"required heating energy"[kJ] = volume of heated water [m^3] x (bath temperature – initial water temperature)[°C] x density of water [kg/ m^3] x specific heat of water [kJ/kg*°C]
where:

- initial water temperature = 18 °C for W4; 16 °C for W3.
- density of water = 1 kg/ m^3
- specific heat of water = 4.1867 kJ/kg*°C

The value of "required heating energy" was calculated for each equipment of the I15 company and total methane consumption was allocated on the basis of the factor "total methane/total "required heating energy".

Table 3.4 shows the annual consumption of methane and steam, and the factors used for allocation. Table 3.5 shows the calculation procedure for steam consumption of the processes of the selected production lines.

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

	Unit	Value	Comment
steam consumption	kg/year	45877000	
steam consumption for thermosetting	kg/yr	2351730	1 kg steam/1 kg textile
steam for water heating	kg/yr	42920270	
total “required heating energy”	kJ/yr	9035173.7	for indirect heating
factor “steam/ required heating energy”	kg/kJ	4.75	
methane consumption of I15 (for production processes and shed heating)	m^3 /yr	3919499	
methane consumption for production processes	m^3 /yr	3723524	95% of methane consumption in I15
factor “methane/steam”	m^3 /kg	0.082	

Table 3.5 Calculation of process specific steam consumptions

	Heated water	Water temperature	Required heating energy/year	Total specific consumption of steam/year	Specific consumption of steam for thermosetting
	(m^3/yr)	**(°C)**	**(kJ/yr)**	**(kg /yr)**	**(kg/yr)**
Silk continuous scouring					
bath	3705	96	1209936	5747624	
ammonia treatment	20378	60	3583272	17021810	
total			4793208	22769434	
Silk dark acid dyeing					
bath	253	60	44549	211623	
total			44549	211623	
Kids washing					
2nd rinsing	4018	60	740245	3516427	
total			740245	3516427	
Acid printed saturated steaming					
steaming	318			23320	
Acid printed washing					
1st bath	210	40	19341	91879	
2nd bath	210	40	19341	91879	
1st rinsing	210	40	19341	91879	
3rd bath	210	40	19341	91879	
total			77366	367515	
Morbidol softener finishing					
thermosetting	38	130			193090
total					193090

3.2.1.4 Consumption of chemicals

Table 3.6 shows the concentration of chemicals used for each process. The mass of chemicals has been calculated on the basis of consumed water (see Chapter 3.1.1.1) or treated fabric (when concentration is defined in g of chemicals/kg fabric or kg of chemicals/100 kg fabric [%]).

Table 3.6 Concentration of chemicals

	soda solvay (24008)	Soaping agent (50012)	Acetic acid (21006)	Lubricating agent (4000	Antifoaming agent (28007)	Antifoaming agent (2800	Acid dyestuffs	Soaping agent (50022)	Soaping agent (5000	Equalizing agent (54007)	Soaping agent (5001	Solubilizing agent (4406)	Regenerating agent-NaCl (44013)	Regenerating agent HCl (21008)	Regenerating agent NaOH (24005)	Solvent (53002)	Sequestering agente (50011)	Acid thickener	Thickening agent (22025)	Anti fermentative	Sodium chloride (44012)	Ammonia a(24007)	Stabilising agent (24004)	Dispersant agent (5200	Acid colour	Acid printing paste	Acid donor (21004)	Deoxygenating agent	Conditioning agent
	g/l	g/l	g/l	g/l	g/l	g/Kg	%	g/l	g/l	g/l	g/l	g/kg	kg	kg	kg	g/kg	g/l	g/kg	g/kg	g/kg	g/l	l	ml	g/l	%	kg/l	g/kg	g/l	
Silk Continuous scouring																													
bath	1.5	5						6									0.5							1					
ammonia treatment					0.3																	330	200						
Silk dark acid dyeing																													
bath			1	1	0.5		1.5			0.5											5								
Acid blender prep.																													
mixing						10						30							60	1.5							30		
Acid colour prep.																													
mixing							40					50				40		500									30		
Acid colours thickeners prep.																													
mixing						10													120	1.5									
Acid printing paste prep.																													
mixing																		1:50							0.2				
Flat table acid printing																													
squeezing																										35			
Acid printed washing																													
1st bath									1		0.5													0.5					
2nd bath									1		0.5													0.5					
3rd bath									1		0.5													0.5					
De-ironing																													
Regeneration													250																
Softening of water																													
Regeneration													260																

3.2.1.5 Discharged water

Table 3.7 shows the COD and TSS concentrations of discharged water. Masses of total COD and TSS were calculated by multiplying the concentration values and the discharged water at each process step (see Chapter 3.1).

Table 3.7 Discharged water

	Volume (m^3/yr)	COD (mg/l)	TSS (mg/l)
Silk continuous scouring			
scouring	3705	18000	22
refreshing water	3705	18000	22
ammonia treatment	20378	650	10
1st rinsing	20378	140	10
2nd rinsing	20378	132	10
Silk dark acid dyeing			
dyeing bath	253	950	10
1st rinsing	253	220	10
2nd rinsing	253	80	20
filling	253	23	23
Acid blender preparation			
washing	883	1000	250
Acid colour preparation			
washing	441	1000	250
Acid colour thickeners preparation			
discharge	44	1000	250
Acid printing paste preparation			
washing	57692	1000	250
Flat table acid printing			
table washing	452	200	50
Printing screen washing			
washing	72331	400	67
rinsing	72331	150	20
Kids washing			
1st rinsing	4018	300	87
2nd rinsing	4018	50	20
3rd rinsing	4018	80	32
4th rinsing	4018	150	60
Acid printing saturated steaming			
washing	318	300	10
Acid printed washing			
doping bath	210	300	20
1st bath	210	1108	68
2nd bath	210	830	35
1st rinsing	210	31	5
3rd bath	210	428	10
2nd rinsing	210	41	5
3rd rinsing	210	24	3
Morbidol softener finishing			
discharge	38	41500	1177
Rapid filtration of water			
backwashing	793	100	10

	Volume (m^3/yr)	COD (mg/l)	TSS (mg/l)
rinsing	317	50	5
De-ironing			
backwashing	17	150	15
regeneration	26	100	10
rinsing	9	50	5
Softening of water			
backwashing	159	150	15
regeneration	239	100	10
rinsing	80	50	5
Demineralisation			
1st backwashing	64	150	15
cationic regeneration	96	100	10
1st Rinsing	32	50	5
2nd backwashing	20	150	15
anionic regeneration	29	100	10
2nd rinsing	10	50	5

3.2.1.6 Airborne emission

PIDACS specifies for each emission source, typically a specific equipment, the chimney flow rate and the contaminant concentration. For LCA purposes the contaminant emissions in the environment have been calculated as: [emission source flow rate]x[equipment run time]x [contaminant concentration]. If the concentration has been indicated as < limit value, an average of the specific limit value has been assumed.

Concerning processes of the selected production lines in I15 company, there were emission sources related to Steamer, Rameuse and Flat screen table equipments (see Tab.3.8).
Table 3.9. shows the calculation of flow rates related to processes.

Table 3.8: Emission sources

Type	Emission source	Flow rate [Nm^3/h]
G4	Steamer ST1	2787
G6	Rameuse R1	9259
G9	Flat screen table FT1-FT5	2226

Table 3.9:Calculation of flow rates of processes based on working hours

Process	Emission source	Working hours	Emission type	Off-gas flow rate (Nm^3/yr)
Flat table acid printing	Flat screen table FT1-FT5	4519	G9	10059294
Acid printed saturated steaming	Steamer S1	1166.2	G4	3250199.4
Morbidol softener finishing	Rameuse R1	1072.7	G6	9932129.3

Table 3.10: Emission concentrations

Type	G4	G6	G9
Ammonia [mg/Nm^3]	15.32	3.03	1.1
Aldehydes [mg/Nm^3]	1.34	0.61	<0.10
VOC [mg/Nm^3]	0,.80	2.37	1.03

3.2.1.7 Solid waste

The annual solid waste production of the company is specified in the PIDACS. The total waste quantity has been allocated to the reference flow of the analysed product systems on a mass basis. Table 3.11 describes annual values.

Table 3.11 Production of waste

	annual production (kg/yr)	destination of waste
040213-Dyes and pigments	3430	Dump
150101-board sand paper	86610	Reuse
070304-Organic solvents and washing solutions	173510	Dump
150106-Various materials packing	196730	Dump
170405 iron and steel	140320	Reuse
Exhausted ionic exchange resins	460	Dump

3.2.2 Production and transport of chemicals

Data on chemicals production were collected by a comprehensive review of the chemicals Life Cycle Inventories (LCI) available in commercial databases and software [6-11] and by direct contacts with the main textile chemicals manufacturers.
Table 3.12 summarises the sources used for the production of each chemical of System A and B. It must be highlighted that the LCA study has a relevant lack of data on chemicals production: 49% of chemicals in System A and 82% of chemicals in System B were excluded from the product system. These chemicals were treated as flows and characterised in the impact assessment by the EDIP method (see Chapter 2.2.8).
In the Interpretation phase of the LCA study, a sensitivity check was made to evaluate the influence of the lack of data about production of chemicals. Surrogate inventory data about the production of organic chemicals [12] were applied to evaluate the sensitivity of the product system (see Chapter 5.2.2.2).

Transport of chemicals was considered on the basis of PIDACS data. Transport modules of the TEAM database were selected on the basis of type of freight. “Ton x km” values were calculated by multiplying transported mass and distance values. (see Table 3.13)

Table 3.12 Chemicals

Chemical class	Commercial Name	Composition	Source
soaping agent (50012)	Sapojet seta liq.		-
soaping agent (50022)	Sapone verde	Sodium hydroxide	TEAM
soaping agent (50005)	Tanaterge SW-LF	Fatty etoxylate amine solution	-
soaping agent (50016)	Cesapon C4		-
salt (24008)	soda solvay	sodium carbonate	TEAM
Acid (21006)	Acetic acid	Acrilic polymer sodic salt	TEAM
Acid colour			-
Acid printing paste			-
Lubricating agent (40002)	Lubisol AM		-
Antifoaming agent (28007)	Disareante TO	Ethoxilate fatty alchols	-
Antifoaming agent (28009)	Nofome NS	Aliphatic hydrocarbons	-
Acid donor (21004)	Ammonium tartrate	Tartaric acid and ammonia compound	-
Acid dyestuff	Giallo supranol 4GL/Rosso supranol 3BW/Azzurro acido F6B/Nero nichelan WA		-
Acid thickener			-
Anti fermentative agent (44017)	Preventol-P840		-
Base (24007)	Ammonia		TEAM
Dispersant agent (52008)	Chelam 30/N		-
Equalizing agent (54007)	Indigol SCKN	Fatty amines condensation products	-
Sequestering agent (50011)	Biorol OW/60		-
Solvent (53002)	Gliecina A		-
Solubilizing agent (44006)	Urea tecnica	Carbamide	-
Stabilising agent (24004)	Trietanolammina	Tri-ethanol-amyne	-
regenerating agent salt-NaCl (44013)	sodium chloride		TEAM
regenerating agent base-NaOH (24005)	sodium hydroxide		TEAM
regenerating agent-acid HCl (21008)	chloric acid		TEAM
deoxygenating agent	Plusammina 2014		-
conditioning agent	condizionante 2041C		-
Thickening agent (22025)	Printex SR-13		-

Table 3.13 Types and distances of transport of chemicals

Chemical class	Supplier	Type of freight	Distance from delivery [km]
soaping agent (50012)	Lamberti S.p.A.	3,5 tons< Lorry	< 50
soaping agent (50022)	Saponificio varesino S.r.l.	3,5 tons< Lorry	< 50
soaping agent (50005)	Bayer S.p.A.	3,5 tons< Lorry	< 50
soaping agent (50016)	Lamberti S.p.A.	3,5 tons< Lorry	< 50
salt (24008)	Allchital S.p.A.	3,5 tons< Lorry	< 50
Acid (21006)	Allchital S.p.A.-C.P.L.srl	3,5 tons< Lorry	< 50
Acid colour	.	3,5 tons< Lorry	< 50
Acid printing paste		3,5 tons< Lorry	< 50
Lubricating agent (40002)	Lamberti S.p.A.	3,5 tons<Lorry	<50
Antifoaming agent (28007)	Chemicals and colours	3,5 tons< Lorry	< 50
Antifoaming agent (28009)	Sybron chimica Italia srl- Bayer S.p.A.	3,5 tons< Lorry	< 50
Acid donor (21004)	Gammatex S.r.l.-	3,5 tons<Lorry	<50
Acid thickener		3,5 tons<Lorry	< 50
Acid dyestuff		3,5 tons< Lorry	< 100
Anti fermentative agent (44017)		3,5 tons< Lorry	< 50
Base (24007)	Allchital S.p.A.	3,5 tons< Lorry	< 50
Dispersant agent (52008)	Lamberti S.p.A	3,5 tons< Lorry	< 50
Equalizing agent (54007)	Dalton S.p.A.-	3,5 tons< Lorry	< 50
Sequestering agent (50011)	Lamberti S.p.A –Cesalpinia chemicals S.p.A.	3,5 tons< Lorry	< 50
Solvent (53002)	BASF	3,5 tons< Lorry	< 50
Solubilizing agent (44006)	C.P.L. srl	3,5 tons< Lorry	< 50
Stabilising agent (24004)	Allchital S.p.A	3,5 tons< Lorry	< 50
regenerating agent salt-NaCl (44013)	C.P.L. srl	3,5 tons< Lorry	< 100
regenerating agent base-NaOH (24005)	Allchital S.p.A-C.P.L. srl	3,5 tons< Lorry	< 100
regenerating agent-acid HCl (21008)	Allchital S.p.A	3,5 tons< Lorry	< 100
deoxygenating agent	Facci service srl -	3,5 tons< Lorry<12 tons	<100
conditioning agent	Facci service srl-	3,5 tons< Lorry<12 tons	<100
Thickening agent (22025)	Lamberti S.p.A	3,5 tons< Lorry	< 50

3.2.3 Energy production

Modules of TEAM 3.0 were used for the production processes of electrical, thermal and mechanical 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 I15 consumes 0.082 m^3 of methane for the production of 1 kg steam. This amount of consumed methane corresponds to 2.6686 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].

The model predefines some technical variables that influence methane consumption. Concerning I15 company, the following variables were modified:

- Initial temperature of water: 16 ^oC
- Final temperature of steam: 159.35 ^oC
- Boiler yield: 1

These variables result the consumption of 2.6686 MJ of energy / 1 kg of steam.

3.2.4 Waste water treatment plant (WWTP)

Table 3.14 summarizes the data used to model the WWTP.

Table 3.14 Data use for the WWTP

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

3.3 *Results of inventory analysis*

Results of the inventory analysis were preliminary analysed evaluated with the impact assessment methods. Significant flows - whose summed contribution is more than 99% for an impact category- were selected. Table 3.15, 3.16 and 3.17shows the quantities of these main flows, as well as water consumption, COD and TSS emission of the textile industrial processes.

Table 3.15 Results of inventory analysis of I15 silk fabric-System A (only main flows are listed)

	Flow	Units	Total	Continuous scouring	Dark acid dyeing	Morbidol finishing	Rapid Filtration	De-ironing	Softening	Wastewater treatment plant
INPUT	(r) Iron (Fe, ore)	kg	8,91E-01	7,28E-01	1,16E-01	4,14E-02	0,00E+00	9,22E-04	1,17E-03	4,14E-03
	(r) Natural Gas (in ground)	kg	1,85E+02	1,53E+02	2,37E+01	7,82E+00	0,00E+00	1,15E-01	1,46E-01	5,15E-01
	(r) Oil (in ground)	kg	1,02E+01	4,01E+00	1,35E+00	2,88E+00	0,00E+00	2,91E-01	3,35E-01	1,38E+00
	(r) Uranium (U, ore)	kg	3,62E-04	3,00E-04	4,75E-05	1,32E-05	0,00E+00	1,02E-08	1,31E-06	4,58E-08
	Water: Well	litre	3,31E+03	-	-	-	-	3,31E+03	-	-
	Water: Industrial	litre	5,22E+03	-	-	-	5,20E+03	-	-	-
	Water: from Softening	litre	-	6,71E+03	8,32E+02	1,20E+02	0,00E+00	0,00E+00	0,00E+00	0,00E+00
	Water: from Storage	litre	-	0,00E+00	8,32E+02	0,00E+00	0,00E+00	7,69E-01	7,98E+03	0,00E+00
	Water: from Filtration	litre	-	0,00E+00	0,00E+00	0,00E+00	1,64E+01	0,00E+00	0,00E+00	0,00E+00
	Water: Public Network	litre	4,37E+01	4,37E+01	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
	Water: Unspecified Origin	litre	4,33E+02	3,28E+02	5,90E+01	2,80E+01	0,00E+00	1,44E+00	1,00E+01	6,76E+00
OUTPUT	(a) Aldehyde (unspecified)	g	3,87E+00	4,45E-03	7,20E-04	3,14E+00	0,00E+00	7,34E-06	7,28E-01	3,37E-05
	(a) Alkane (unspecified)	g	2,18E+01	1,75E+01	2,87E+00	1,13E+00	0,00E+00	3,70E-02	4,31E-02	1,68E-01
	(a) Ammonia (NH3)	g	2,46E+01	6,77E-01	4,28E-03	1,56E+01	0,00E+00	3,89E-04	8,32E+00	1,75E-03
	(a) Arsenic (As)	g	7,69E-03	3,76E-03	8,59E-04	1,86E-03	0,00E+00	1,82E-04	2,09E-04	8,18E-04
	(a) Benzene (C6H6)	g	3,41E+00	2,70E+00	5,05E-01	1,66E-01	0,00E+00	5,22E-03	7,30E-03	2,40E-02
	(a) Butane (n-C4H10)	g	7,35E+00	5,41E+00	9,25E-01	6,92E-01	0,00E+00	4,83E-02	5,34E-02	2,22E-01
	(a) Cadmium (Cd)	g	1,20E-02	4,61E-03	1,24E-03	3,66E-03	0,00E+00	3,72E-04	3,90E-04	1,67E-03
	(a) Carbon Dioxide (CO2, fossil)	g	4,97E+05	3,94E+05	6,29E+04	3,03E+04	0,00E+00	1,40E+03	1,70E+03	6,50E+03
	(a) Ethane (C2H6)	g	3,38E+01	2,24E+01	4,13E+00	4,66E+00	0,00E+00	3,93E-01	4,23E-01	1,78E+00
	(a) Ethylene (C2H4)	g	9,01E+01	7,40E+01	1,17E+01	3,92E+00	0,00E+00	6,29E-02	8,57E-02	2,83E-01
	(a) Hydrocarbons (except methane)	g	1,67E+02	1,06E+02	2,30E+01	2,34E+01	0,00E+00	2,02E+00	2,50E+00	9,89E+00
	(a) Hydrogen Chloride (HCl)	g	6,77E+00	4,08E+00	8,12E-01	1,15E+00	0,00E+00	1,05E-01	1,50E-01	4,69E-01
	(a) Lead (Pb)	g	5,69E-02	3,05E-02	1,30E-02	8,19E-03	0,00E+00	7,89E-04	8,99E-04	3,55E-03
	(a) Methane (CH4)	g	8,78E+02	5,90E+02	9,78E+01	1,21E+02	0,00E+00	1,05E+01	1,15E+01	4,75E+01
	(a) Nickel (Ni)	g	2,36E-01	9,14E-02	2,45E-02	7,22E-02	0,00E+00	7,33E-03	7,67E-03	3,29E-02
	(a) Nitrogen Oxides (NOx as NO2)	g	3,44E+02	2,45E+02	4,28E+01	3,44E+01	0,00E+00	2,59E+00	4,10E+00	1,43E+01
	(a) Nitrous Oxide (N2O)	g	1,92E+00	1,25E+00	2,53E-01	2,40E-01	0,00E+00	2,06E-02	3,58E-02	1,23E-01

	Flow	Units	Total	Continuous scouring	Dark acid dyeing	Morbidol finishing	Rapid Filtration	De-ironing	Softening	Wastewater treatment plant
	(a) Propane (C3H8)	g	9,75E+00	6,68E+00	1,20E+00	1,22E+00	0,00E+00	9,90E-02	1,09E-01	4,49E-01
	(a) Sulphur Oxides (SOx as SO2)	g	5,90E+02	2,85E+02	6,38E+01	1,46E+02	0,00E+00	1,44E+01	1,55E+01	6,48E+01
	(a) Vanadium (V)	g	9,13E-01	3,41E-01	9,39E-02	2,87E-01	0,00E+00	2,92E-02	3,05E-02	1,31E-01
	(s) Arsenic (As)	g	1,51E-03	1,24E-03	1,96E-04	6,44E-05	0,00E+00	9,09E-07	1,17E-06	4,09E-06
	(s) Chromium (Cr III, Cr VI)	g	1,89E-02	1,55E-02	2,45E-03	8,06E-04	0,00E+00	1,14E-05	1,46E-05	5,12E-05
	(s) Zinc (Zn)	g	5,66E-02	4,66E-02	7,37E-03	2,42E-03	0,00E+00	3,42E-05	4,38E-05	1,54E-04
	(w) Ammonia (NH4+, NH3, as N)	g	5,73E+01	2,59E-01	8,62E-02	1,28E-01	0,00E+00	1,26E-02	1,64E-02	5,68E+01
	(w) COD (Chemical Oxygen Demand)	g	4,96E+02	2,73E+00	2,28E+00	2,38E-01	0,00E+00	1,41E-02	1,97E-02	4,91E+02
	(w) Nitrate (NO3-)	g	7,47E+01	7,01E-02	4,69E-02	2,54E-02	0,00E+00	2,39E-03	2,57E-03	7,46E+01
	(w) Nitrogenous Matter (unspecified, as N)	g	1,33E+02	2,52E-01	9,97E-02	1,60E-01	0,00E+00	1,61E-02	1,74E-02	1,32E+02
	Wastewater	litre	0,00E+00	6,67E+03	1,66E+03	1,97E+01	1,64E+01	7,69E-01	2,35E+01	0,00E+00
REMINDERS	E Feedstock Energy	MJ	6,73E+01	3,43E+01	1,63E+01	1,04E+01	0,00E+00	9,49E-01	1,03E+00	4,31E+00
	E Fuel Energy	MJ	8,31E+03	6,66E+03	1,05E+03	4,72E+02	0,00E+00	1,92E+01	2,38E+01	8,93E+01
	E Non Renewable Energy	MJ	8,31E+03	6,66E+03	1,06E+03	4,65E+02	0,00E+00	1,85E+01	2,32E+01	8,62E+01
	E Renewable Energy	MJ	6,78E+01	3,31E+01	7,32E+00	1,68E+01	0,00E+00	1,65E+00	1,60E+00	7,39E+00
	E Total Primary Energy	MJ	8,38E+03	6,69E+03	1,07E+03	4,82E+02	0,00E+00	2,02E+01	2,48E+01	9,36E+01
	Electricity	MJ elec	4,76E+02	2,14E+02	4,94E+01	1,30E+02	0,00E+00	1,30E+01	1,24E+01	5,81E+01
	COD to WWTP	kg	1,62E+01	1,48E+01	5,30E-01	8,17E-01	1,08E-03	6,35E-05	1,88E-03	0,00E+00
	TSS to WWTP	kg	1,96E+00	1,91E+00	2,62E-02	2,32E-02	1,08E-04	6,35E-06	1,88E-04	0,00E+00

Table 3.16 Results of inventory analysis of I15 silk fabric-System B (only main flows are listed)

	Flow	Units	Total	Continuous scouring	Printing	Morbidol finishing	Rapid Filtration	De-ironing	Softening	Wastewater treatment plant
INPUT	(r) Iron (Fe, ore)	kg	9,94E-01	7,28E-01	1,99E-01	4,14E-02	0,00E+00	5,50E-03	1,55E-03	1,86E-02
	(r) Natural Gas (in ground)	kg	2,03E+02	1,53E+02	3,94E+01	7,82E+00	0,00E+00	6,83E-01	1,95E-01	2,32E+00
	(r) Oil (in ground)	kg	2,29E+01	4,05E+00	7,60E+00	2,88E+00	0,00E+00	1,74E+00	4,46E-01	6,20E+00
	(r) Uranium (U, ore)	kg	3,87E-04	3,00E-04	7,13E-05	1,32E-05	0,00E+00	6,07E-08	1,75E-06	2,06E-07
	Water: Well	litre	1,52E+04	-	-	-	-	1,52E+04	-	-
	Water: Industrial	litre	2,39E+04	-	-	-	2,38E+04	-	-	-
	Water: from Softening	litre	-	6,71E+03	7,28E+02	1,20E+02	0,00E+00	0,00E+00	0,00E+00	0,00E+00
	Water: from Storage	litre	-	0,00E+00	3,04E+04	0,00E+00	0,00E+00	3,52E+00	8,49E+03	0,00E+00
	Water: from Filtration	litre	-	0,00E+00	0,00E+00	0,00E+00	7,51E+01	0,00E+00	0,00E+00	0,00E+00
	Water: Public Network	litre	4,37E+01	4,37E+01	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
	Water: Unspecified Origin	litre	5,21E+02	3,28E+02	1,12E+02	2,80E+01	0,00E+00	8,60E+00	1,34E+01	3,05E+01
OUTPUT	(a) Aldehyde (unspecified)	g	1,03E+01	4,45E-03	7,11E+00	3,14E+00	0,00E+00	4,38E-05	1,92E-05	1,52E-04
	(a) Alkane (unspecified)	g	2,48E+01	1,75E+01	5,14E+00	1,13E+00	0,00E+00	2,21E-01	5,74E-02	7,55E-01
	(a) Ammonia (NH3)	g	4,51E+01	6,77E-01	2,89E+01	1,56E+01	0,00E+00	2,32E-03	7,71E-04	7,86E-03
	(a) Arsenic (As)	g	1,58E-02	3,77E-03	5,10E-03	1,86E-03	0,00E+00	1,09E-03	2,78E-04	3,68E-03
	(a) Barium (Ba)	g	3,53E-02	1,67E-02	9,30E-03	2,86E-03	0,00E+00	1,36E-03	4,98E-04	4,59E-03
	(a) Benzene (C6H6)	g	3,80E+00	2,73E+00	7,59E-01	1,66E-01	0,00E+00	3,11E-02	9,72E-03	1,08E-01
	(a) Cadmium (Cd)	g	2,82E-02	4,62E-03	9,67E-03	3,66E-03	0,00E+00	2,22E-03	5,19E-04	7,53E-03
	(a) Carbon Dioxide (CO2, fossil)	g	5,91E+05	3,94E+05	1,26E+05	3,03E+04	0,00E+00	8,33E+03	2,27E+03	2,93E+04
	(a) Ethane (C2H6)	g	5,26E+01	2,25E+01	1,45E+01	4,66E+00	0,00E+00	2,34E+00	5,64E-01	8,02E+00
	(a) Ethylene (C2H4)	g	9,93E+01	7,40E+01	1,96E+01	3,92E+00	0,00E+00	3,75E-01	1,14E-01	1,27E+00
	(a) Hydrocarbons (except methane)	g	2,62E+02	1,07E+02	7,15E+01	2,34E+01	0,00E+00	1,20E+01	3,32E+00	4,45E+01
	(a) Lead (Pb)	g	8,62E-02	3,33E-02	2,28E-02	8,19E-03	0,00E+00	4,71E-03	1,20E-03	1,60E-02
	(a) Methane (CH4)	g	1,37E+03	5,90E+02	3,69E+02	1,21E+02	0,00E+00	6,27E+01	1,53E+01	2,14E+02
	(a) Nitrogen Oxides (NOx as NO2)	g	4,82E+02	2,46E+02	1,15E+02	3,44E+01	0,00E+00	1,54E+01	5,46E+00	6,45E+01

Flow	Units	Total	Continuous scouring	Printing	Morbidol finishing	Rapid Filtration	De-ironing	Softening	Wastewater treatment plant
(a) Propane (C3H8)	g	1,46E+01	6,69E+00	3,91E+00	1,22E+00	0,00E+00	5,90E-01	1,44E-01	2,02E+00
(a) Sulphur Oxides (SOx as SO2)	g	1,23E+03	2,86E+02	3,98E+02	1,46E+02	0,00E+00	8,58E+01	2,07E+01	2,92E+02
(a) Vanadium (V)	g	2,19E+00	3,42E-01	7,54E-01	2,87E-01	0,00E+00	1,74E-01	4,07E-02	5,91E-01
(s) Arsenic (As)	g	1,65E-03	1,24E-03	3,25E-04	6,44E-05	0,00E+00	5,42E-06	1,55E-06	1,84E-05
(s) Chromium (Cr III, Cr VI)	g	2,07E-02	1,55E-02	4,07E-03	8,06E-04	0,00E+00	6,78E-05	1,94E-05	2,30E-04
(s) Zinc (Zn)	g	6,22E-02	4,66E-02	1,22E-02	2,42E-03	0,00E+00	2,04E-04	5,83E-05	6,92E-04
(w) Ammonia (NH4+, NH3, as N)	g	2,56E+02	2,63E-01	3,49E-01	1,28E-01	0,00E+00	7,54E-02	2,18E-02	2,56E+02
(w) Benzene (C6H6)	g	3,31E-01	8,02E-02	1,05E-01	3,83E-02	0,00E+00	2,23E-02	5,73E-03	7,98E-02
(w) Cadmium (Cd++)	g	1,06E-03	3,40E-04	3,09E-04	1,08E-04	0,00E+00	5,97E-05	1,69E-05	2,24E-04
(w) Chromium (Cr III)	g	4,35E-02	3,26E-02	8,54E-03	1,69E-03	0,00E+00	1,42E-04	4,08E-05	4,84E-04
(w) COD (Chemical Oxygen Demand)	g	2,21E+03	2,73E+00	9,04E-01	2,38E-01	0,00E+00	8,38E-02	2,62E-02	2,21E+03
(w) Nitrate (NO3-)	g	3,36E+02	7,01E-02	7,19E-02	2,54E-02	0,00E+00	1,43E-02	3,43E-03	3,36E+02
(w) Nitrogenous Matter (unspecified, as N)	g	5,97E+02	2,56E-01	4,25E-01	1,60E-01	0,00E+00	9,58E-02	2,31E-02	5,96E+02
(w) Oils (unspecified)	g	1,00E+01	6,55E+00	2,20E+00	5,36E-01	0,00E+00	1,55E-01	4,10E-02	5,52E-01
Wastewater	litre	0,00E+00	6,67E+03	3,10E+04	1,97E+01	7,51E+01	3,52E+00	2,32E+01	0,00E+00
E Feedstock Energy	MJ	1,01E+02	3,43E+01	3,03E+01	1,04E+01	0,00E+00	5,66E+00	1,38E+00	1,94E+01
E Fuel Energy	MJ	9,71E+03	6,66E+03	2,03E+03	4,72E+02	0,00E+00	1,15E+02	3,17E+01	4,02E+02
E Non Renewable Energy	MJ	9,67E+03	6,66E+03	2,02E+03	4,65E+02	0,00E+00	1,11E+02	3,09E+01	3,88E+02
E Renewable Energy	MJ	1,41E+02	3,31E+01	4,60E+01	1,68E+01	0,00E+00	9,83E+00	2,13E+00	3,33E+01
E Total Primary Energy	MJ	9,81E+03	6,69E+03	2,06E+03	4,82E+02	0,00E+00	1,20E+02	3,31E+01	4,22E+02
Electricity	MJ elec	1,05E+03	2,14E+02	3,49E+02	1,30E+02	0,00E+00	7,73E+01	1,65E+01	2,62E+02
COD to WWTP	kg	3,24E+01	1,48E+01	1,68E+01	8,17E-01	6,44E-03	3,79E-04	2,51E-03	0,00E+00
TSS to WWTP	kg	5,69E+00	1,91E+00	3,75E+00	2,32E-02	6,44E-04	3,79E-05	2,51E-04	0,00E+00

REMINDERS

4 Life cycle impact assessment

Classification and characterisation 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 of System A

In the following paragraphs the graphs of the selected impact assessment categories and inventory data are presented for system A (silk fabric dyeing) to highlight significant issues. Contributions of electricity production, steam production and other issues (such as production and transport of chemicals, gate-to-gate flows etc.) into impact assessment results are visualised, too. If the issue "Others" 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

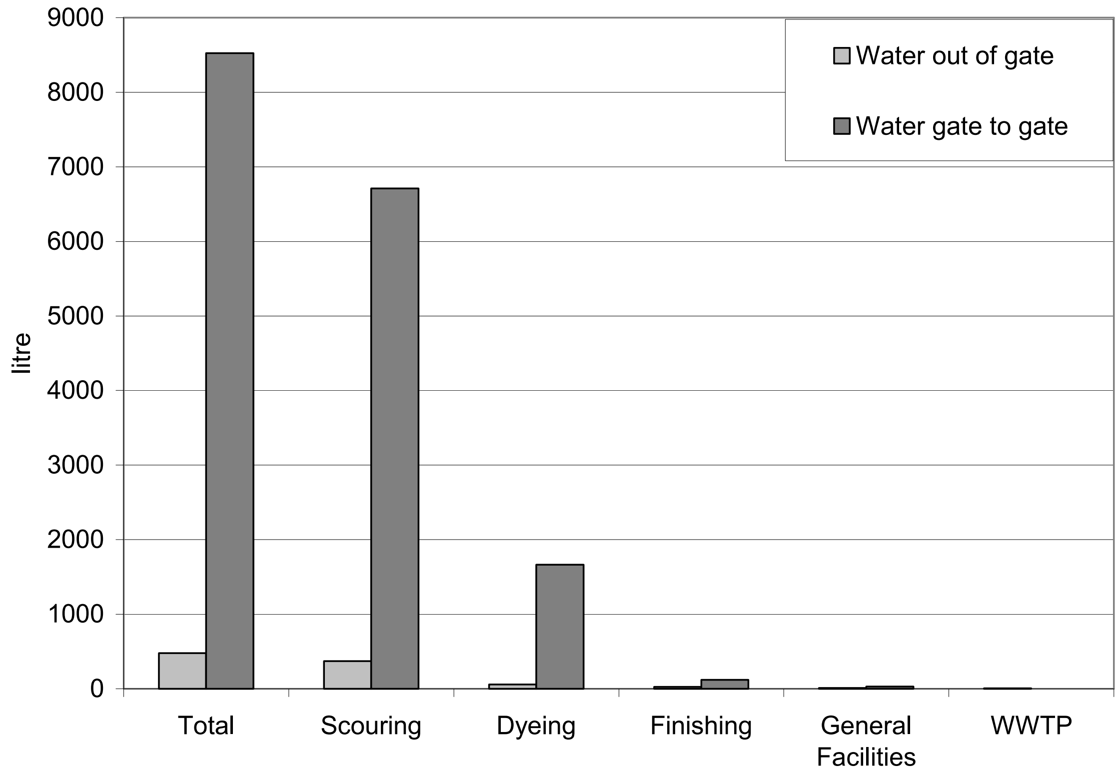

Figure 5.1 Water consumption

5.1.2 COD and TSS emissions

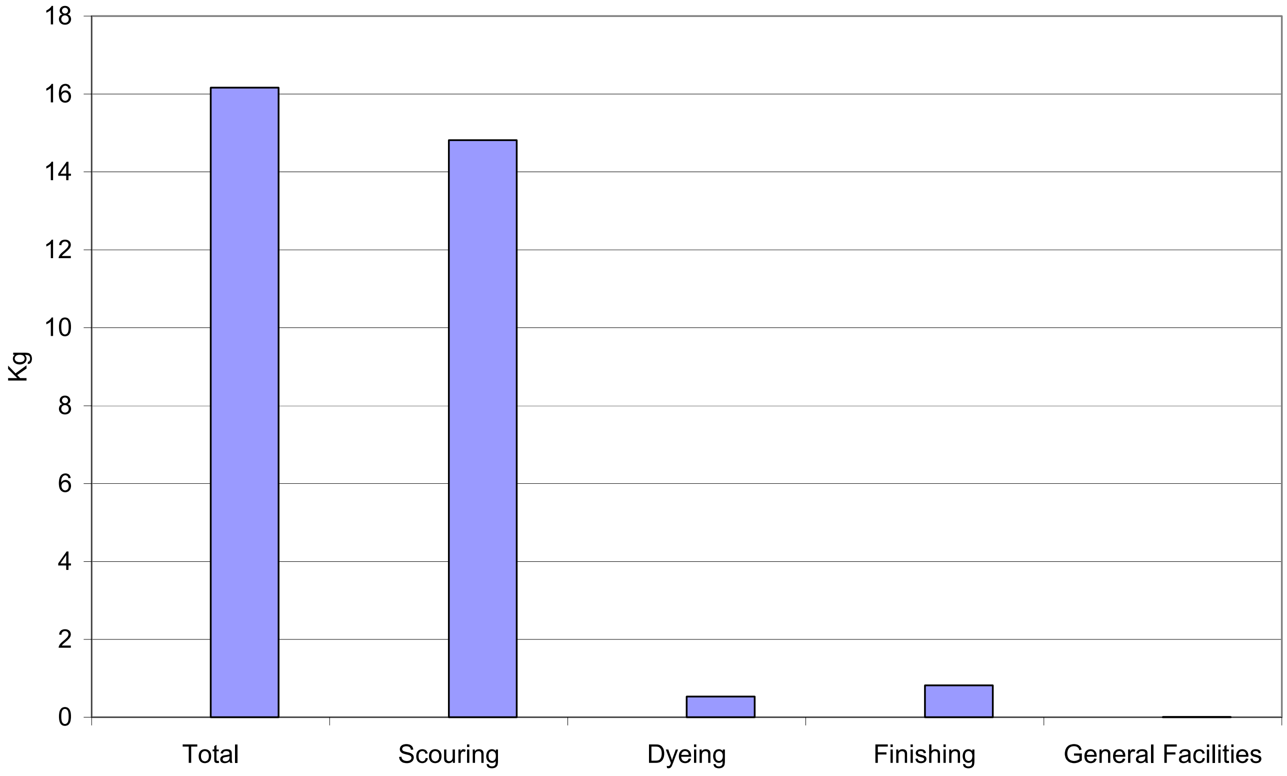

Figure 5.2 COD emission

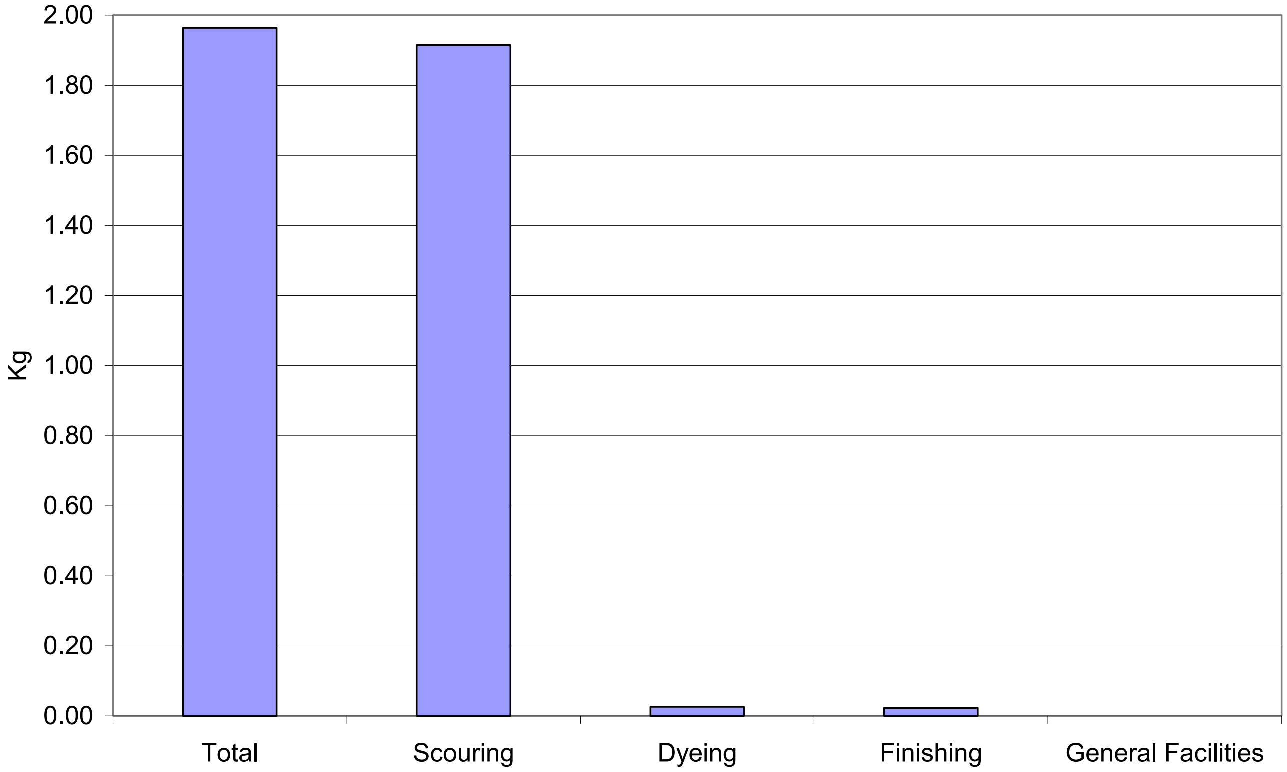

Figure 5.3 TSS emission

5.1.3 Energy indicators

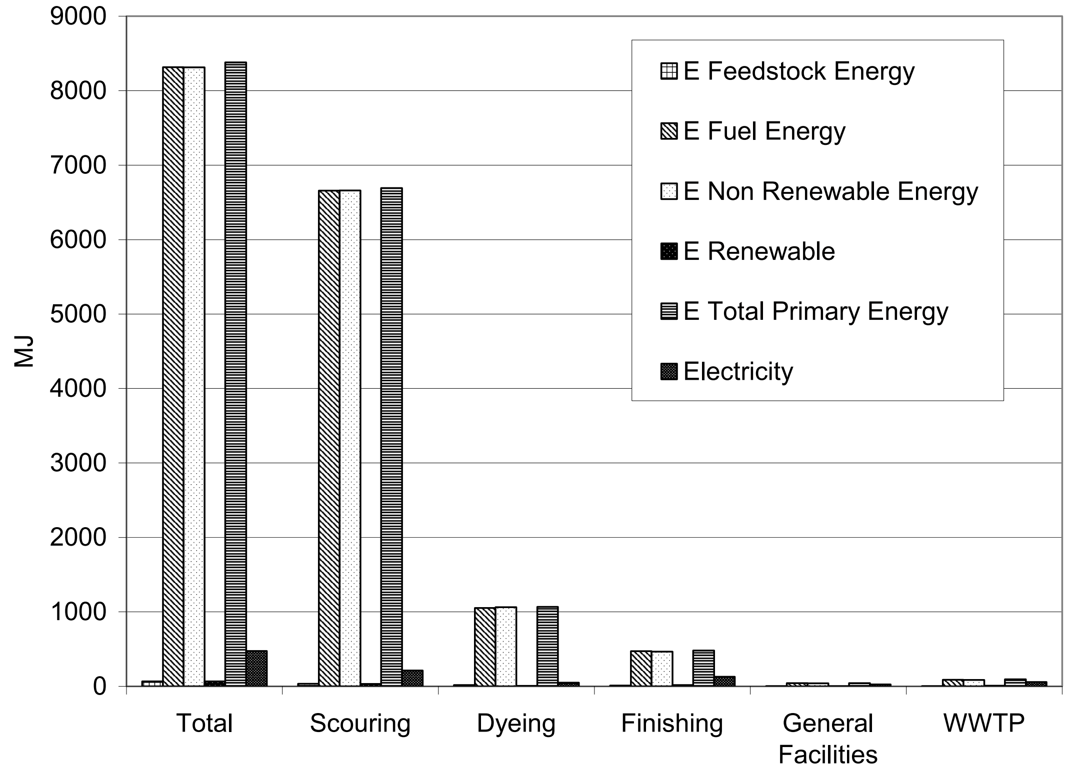

Figure 5.4 Energy indicators

5.1.4 Air Acidification

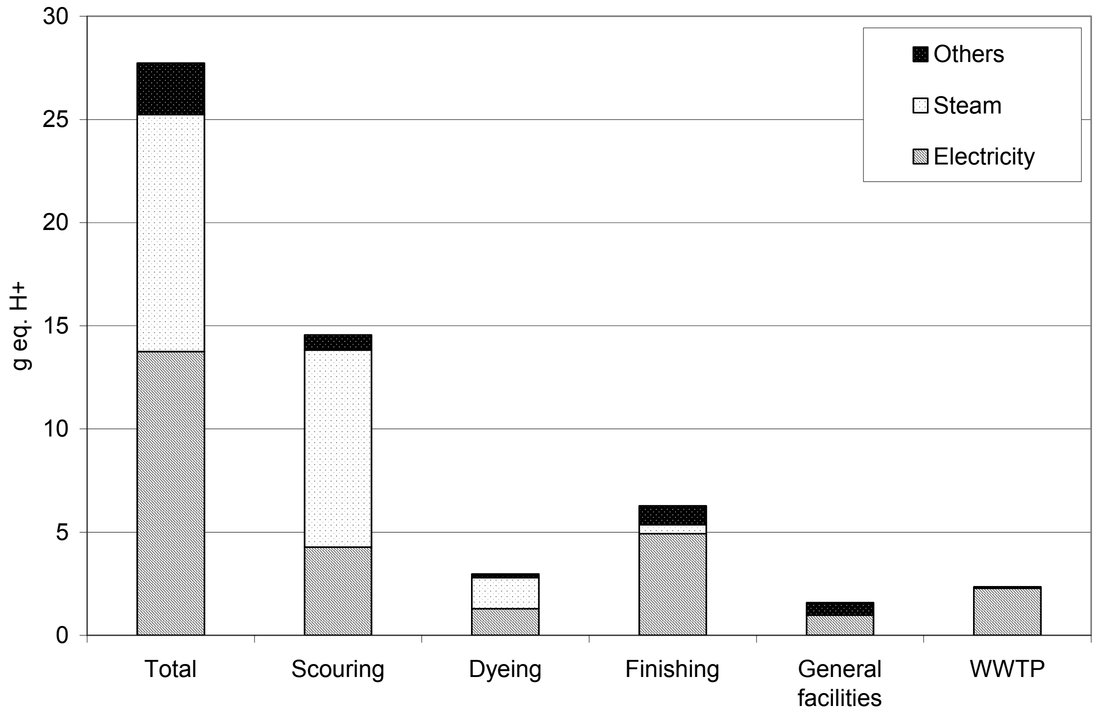

Figure 5.5 Air-Acidification

The main airborne emissions which contribute to total value are sulphur oxides (67%) and nitrogen oxides (27%).The mayor part of the contribution is given from electricity consumption.

5.1.5 Aquatic ecotoxicity

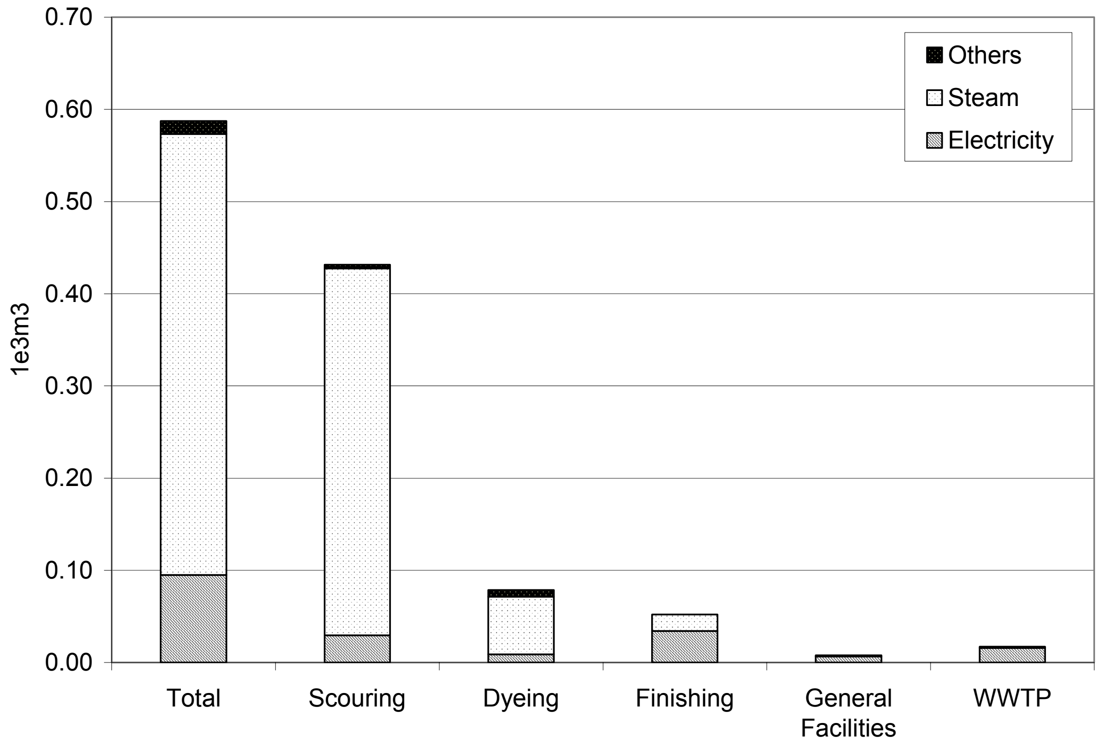

Figure 5.6 Aquatic ecotoxicity

The main waterborne emissions which contribute to total value are oils (71%) and cadmium (21%).

5.1.6 Depletion of non renewable resources

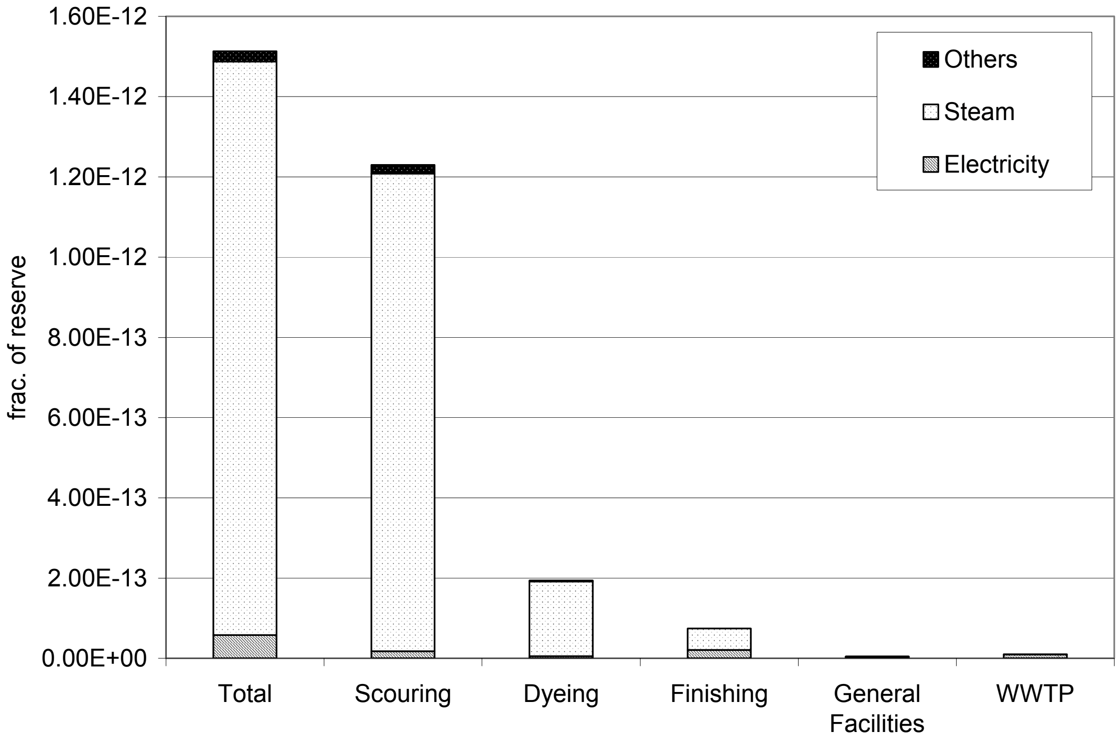

Figure 5.7 Depletion of non renewable resources

The main resource which contributes to total value is natural gas (95%).

5.1.7 Human toxicity

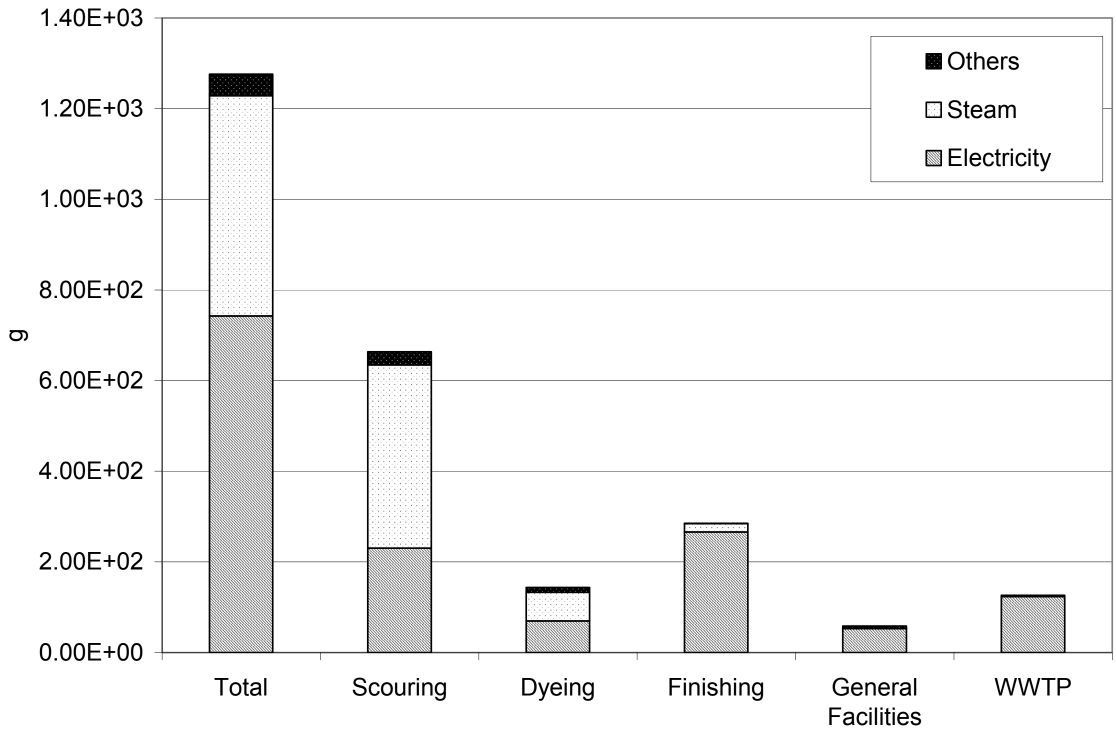

Figure 5.8 Human toxicity

The main airborne emissions which contribute to total value are sulphur oxides (55%), are nitrogen oxides (21%), nickel (9%) and vanadium (9%).

5.1.8 Terrestrial ecotoxicity

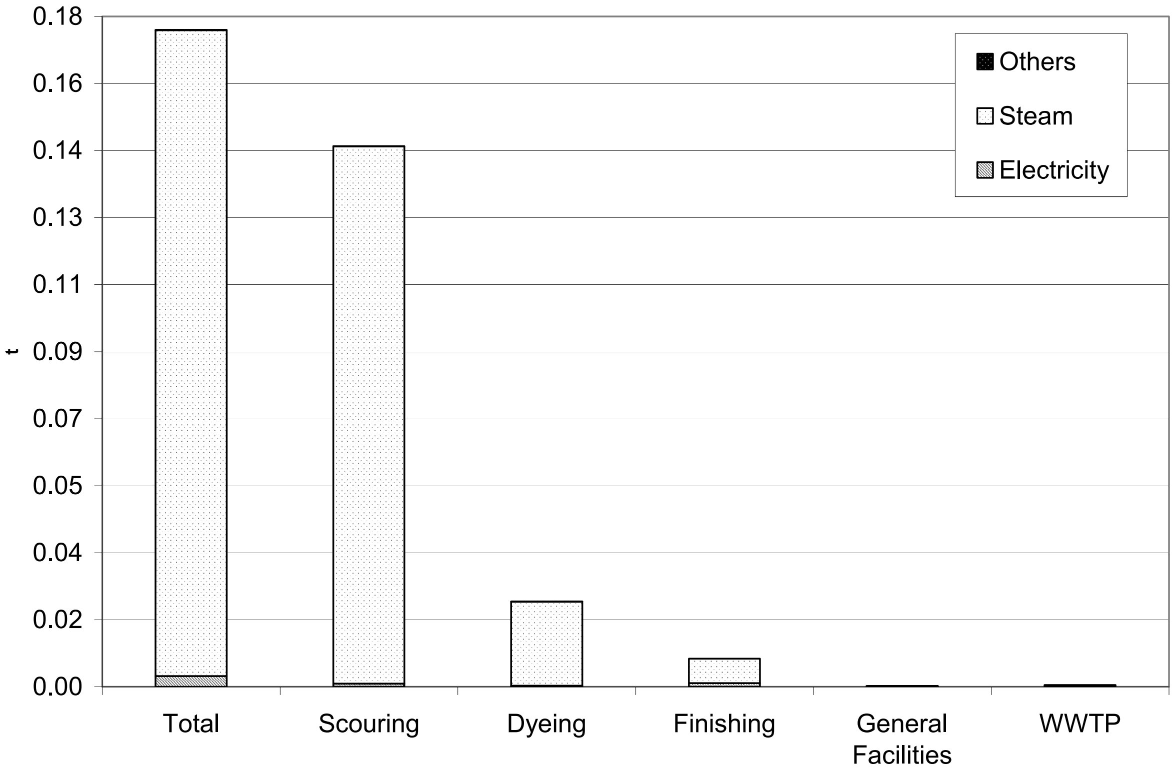

Figure 5.9 Terrestrial ecotoxicity

The main soil emissions which contribute to total value are zinc (83%) and chromium (12%).

5.1.9 Eutrophication

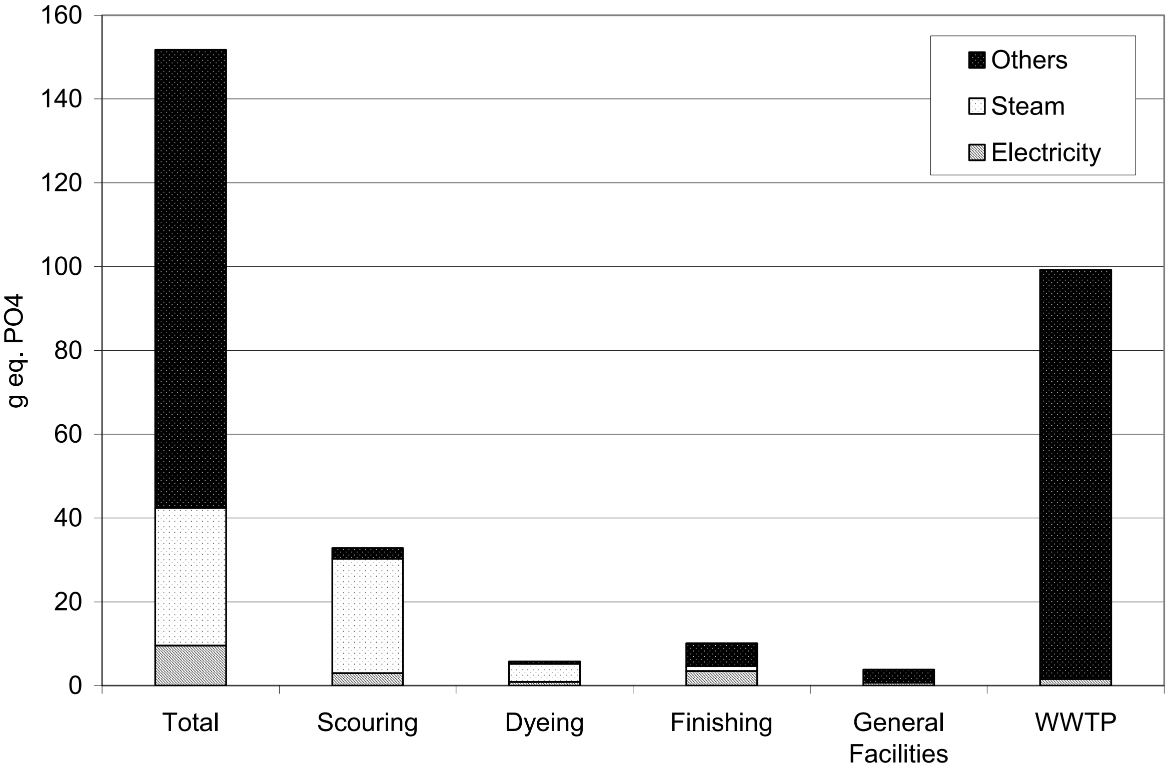

Figure 5.10 Eutrophication

The issue “Others” has very high contribution because of the emissions to water from the waste water treatment plant. The main waterborne emissions which contribute to total value are nitrogenous matter (37%), nitrogen oxides (29%) and ammonia (16%).

5.1.10 Greenhouse effect

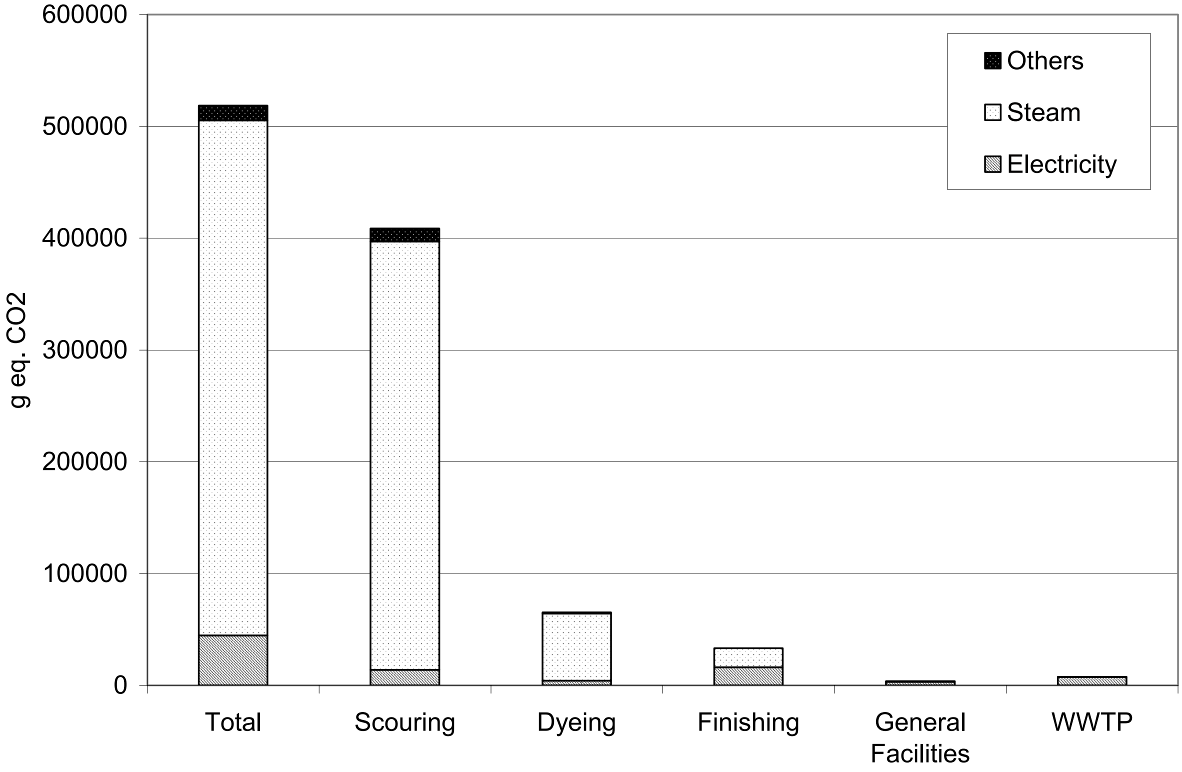

Figure 5.11 Greenhouse effect

The main airborne emission which contributes to total value is carbon dioxide (96%).

5.1.11 Photochemical smog

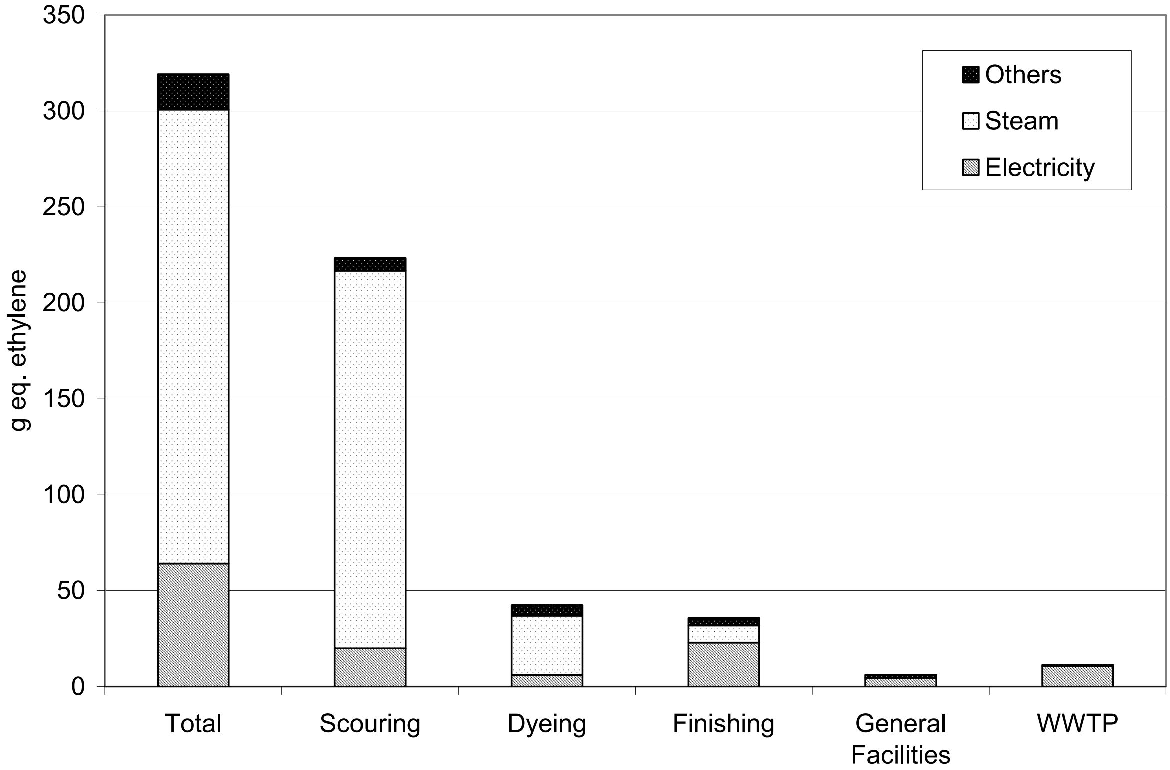

Figure 5.12 Photochemical oxidant formation

The main airborne emissions which contribute to total value are hydrocarbons (42%) and ethylene (28%).

5.1.12 Ecotoxicity of chemicals (screening)

Processes in systems A, B and C do not use chemicals classified with risk phrases R50, R51, R52, R53, R54, R55, R56, R57, R58 and so the total score for the two systems is 0.

5.2 Comparison of System A and System B

Inventory and impact assessment results of and System B were compared to the results of System A. (see Figures 5.13-14)

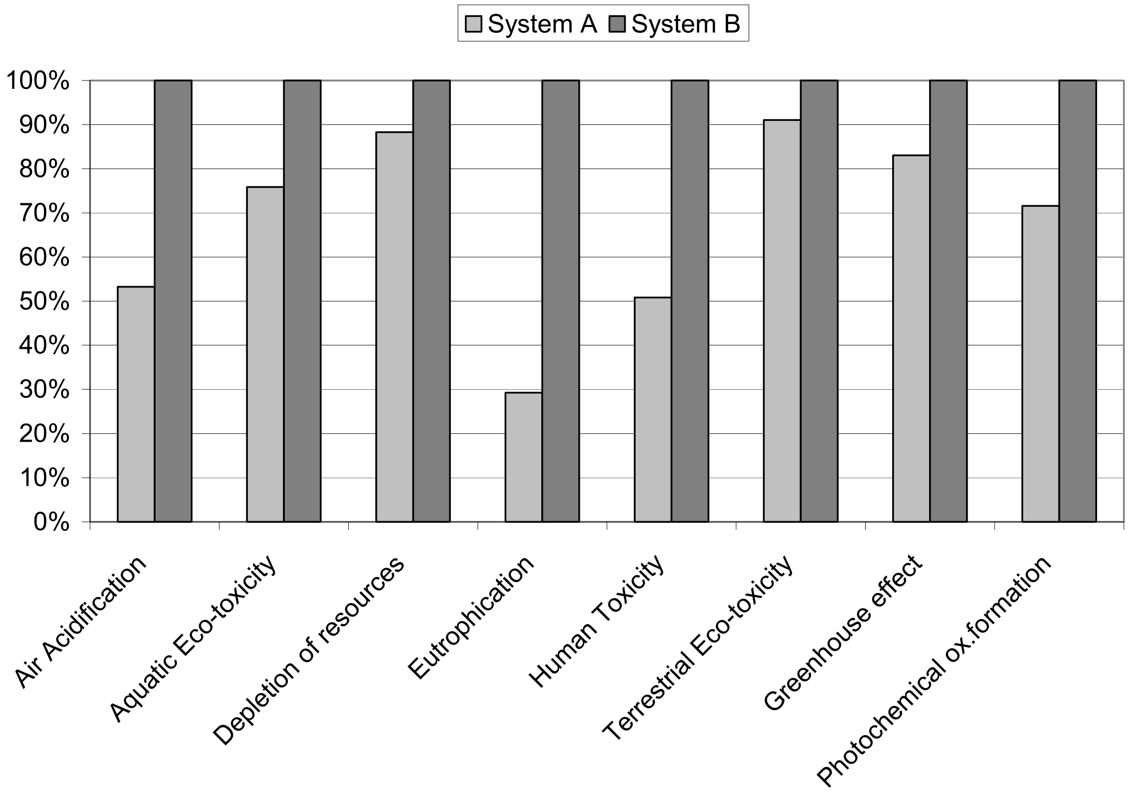

Figure 5.13 Comparison of water consumption, COD and TSS emissions and energy indicators of Systems A and B.

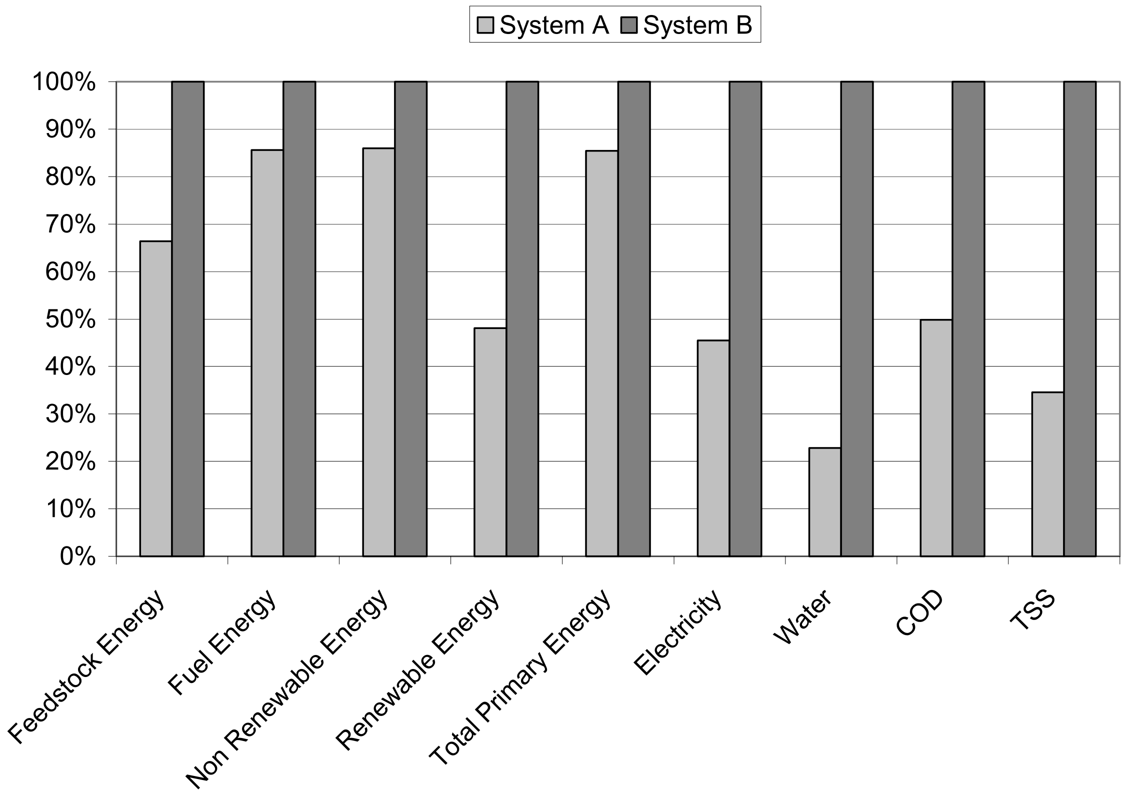

Figure 5.14 Comparison of impact assessment results of Systems A and B.

System B has significantly higher total values for all of the inventory and impact categories (20-55%). The main reason is that printing processes consume more thermal energy (steam) and electricity than direct dyeing processes in Systems A.
COD and TSS are higher in System B because of emissions of printing processes instead of dyeing (Systems A).
Eutrophication value of System A is lower because dyeing process has significantly less amount of wastewater emission than printing processes of Systems B.

5.2.1 Completeness check

The LCA study cannot be considered complete because of the lack of data about production of numerous chemicals used in System A and B. It was decided to check the sensitivity of results to this aspect.

5.2.2 Sensitivity check

5.2.2.1 Allocation of thermal energy

The allocation rule applied for the definition of process specific steam and methane consumption (described in Chapter 3.2.1.3) is based on theoretic calculations and not on direct measurements. The final results of the study identified steam consumption as a significant issue for several inventory and impact categories. A sensitivity check was necessary to analyse the effect of the uncertainty of this aspect to the final results. Table 5.1 shows deviation of the results if steam consumption is increased by 10%.

Table 5.1 Sensitivity check of System A and B to the uncertainty of steam consumption.

	System A	System B
Air Acidification	4%	3%
Aquatic Eco-toxicity	8%	7%
Depletion of non renewable resources	9%	10%
Eutrophication	2%	1%
Human Toxicity	4%	2%
Terrestrial Eco-toxicity	10%	10%
Greenhouse effect	9%	9%
Photochemical oxidant formation	7%	6%
Feedstock Energy	5%	4%
Fuel Energy	9%	9%
Non Renewable Energy	9%	9%
Renewable Energy	3%	2%
Total Primary Energy	9%	9%
Electricity	3%	1%

Nearly 10% uncertainty of steam consumption influence significantly some inventory and impact assessment results (fuel energy, non renewable energy, total primary energy, depletion of non renewable resources, terrestrial eco-toxicity and greenhouse effect).

5.2.2.2 Lack of data on chemicals production.

The lack of data about the production of several chemicals of System A and B can influence final results. To analyse the sensitivity of systems, surrogate inventory data on the production of chemicals were used [12]. Table 5.2 shows how the final results are influenced by the application of these generic data.

Table 5.2 Sensitivity check of Systems A and B to lack of data about surrogate chemicals

	System A	System B
Air Acidification	7%	11%
Aquatic Eco-toxicity	3%	6%
Depletion of non renewable resources	1%	4%
Eutrophication	1%	1%
Human Toxicity	7%	11%
Terrestrial Eco-toxicity	0%	1%
Greenhouse effect	2%	5%
Photochemical oxidant formation	3%	7%
Water used (total)	0%	0%
Feedstock Energy	52%	105%
Fuel Energy	2%	5%
Non Renewable Energy	2%	6%
Renewable Energy	17%	25%
Total Primary Energy	2%	6%
Electricity	14%	19%

Both systems are sensitive to the lack of data on chemicals for some energy indicators (feedstock energy, renewable energy, electricity). These energy categories have low total values compared to other energy indicators (see Figure 5.4), so electricity and heat fuel oil consumption for organic chemicals production can influence significantly these results.
Results of System B are also sensitive for acidification and human toxicity because of the big quantity of chemicals (such as thickening agent, acid donor, acid printing-pastes and solubilizing agent) used for printing processes.

5.2.3 Consistency check

This LCA study can be considered consistent. Most of the data are from PIDACS or from TEAM 3.0 modules which guarantee a good general consistency. The only process having a different origin is the waste water treatment plant, which influence on the overall system is limited.

6 Conclusions

For the Life Cycle Assessment of silk fabric according to System A the following main conclusions can be drawn:

- The product system requires 8520 litre of water for 100 kg of product. Less than 500 litre are consumed out of the company gates. Water consumptions of silk continuous scouring in mezzera (79 % on total) and direct dyeing in boat (20% on total) are the highest.
- COD and TSS emissions arise mainly from scouring process (92-97%)
- For several inventory and impact assessment categories silk continuous scouring in mezzera has the higher contribution (45-80%) followed by direct dyeing in boat (10-

24%) or softener finishing (5-27%). These results are always related to steam and electricity consumptions. Production of steam contributes mainly to aquatic ecotoxicity, greenhouse effect, photochemical smog, terrestrial ecotoxicity and depletion of non renewable resources; production of electricity contributes mainly to human toxicity; and both of these aspects are responsible for air acidification. Eutrophication arises mainly from the “others”.

- Hot-spot of eutrophication impact category is the waste water treatment plant because of its emissions to water (65%).

Comparison and analysis of two silk fabric production lines (System A and B) highlighted that:

- Printing processes require more thermal energy (production of steam) and electricity than direct dyeing processes (in boat). For this reason System B has significantly (20-55%) higher total values for several inventory and impact categories (such as fuel energy, non renewable energy, total primary energy, depletion of non renewable resources, terrestrial eco-toxicity, greenhouse effect).
- Direct dyeing in boat (System A) has significantly less amount of wastewater emission than printing processes of Systems B.
- Dark direct dyeing of silk (System A) has much lower COD and TSS emissions than printing processes (system B).
- Production of chemicals has not significant contribution to final results. It must be highlighted that the LCA study has a relevant lack of data on chemicals production. A sensitivity check, using surrogate data demonstrated the importance of this aspect: electricity and heat fuel oil consumption of organic chemicals production can modify significantly the results of some energy indicators (feedstock energy, renewable energy, electricity). Moreover, acidification and human toxicity results of System B are sensitive for the lack of data about chemicals (thickening agent, acid donor, acid printing-pastes and solubilizing agent) consumed in printing processes.
- Process specific steam consumption was calculated applying an allocation rule based on the energy need for heating of process water. A sensitivity check demonstrated that despite 10% uncertainty of this calculation has a significant influence on some categories, the study results are not invalidated.

References

[1] ISO 14040 Environmental management - Life cycle assessment - Principles and framework, 1997.
[2] ISO 14041 Environmental management - Life cycle assessment - Goal and scope definition and inventory analysis, 1998.
[3] ISO 14042 Environmental management - Life cycle assessment - Life cycle impact assessment, 2000.
[4] ISO 14043 Environmental management - Life cycle assessment - Life cycle interpretation, 2000.
[5] European Commission: Integrated Product Prevention and Control – Reference document on Best Available Techniques for the textile industry, November 2002.
[6] Ecobilan Group: TEAM 3.0 – Tools for Environmental Analyses and Management, 1999.
[7] Pré Consultants: Simapro 5.0, 2001.
[8] KCL EcoData, LCI modules database, KCL Science and consulting, Finland.
[9] IVAM Environmental Research: Database IVAM 2.0, in: Simapro 5.0, 1998.
[10] Boustead Model, Boustead consulting Ltd, Horsham, West Sussex, UK.
[11] PE Europe, IKP University of Stuttgart: GaBi 3.2 Sofware System for Life Cycle Engineering, Professional Database, 1998.
[12] Frischknecht et al. "Oekoinventare von Energiesystem", in: Simapro 5.0 DataBase Standard Library ETH-ESU 1996.
[13] Ferri, F. and Tarantini, M., AQUASAVE project-Life cycle Assessment of drinking water and wastewater treatments of Bologna city (in Italian), ENEA OT-SCA-00024 Rev 2, 2001
[14] IPPC Guideline for National Greenhouse Gas Inventories: Reference Manual, 1996.
[15] H. Wenzel, M. Hauschild and L. Altig "Environmental Assessment of products" Vol II Chapman&Hall 1984.

Annex 1 : Structure and content of PIDACS

1) NOTES ON DATA COLLECTION.

- Reference year:.
- Sampling and data collection period:
- Compiler name:
- Company contact people:

2) GENERAL DATA.

a) Production:

Reference year:

Fiber	*Type*	*(%) of total weight*	*processed linear meters/yr*	*kg per linear meter*	*processed kg/yr*
TOTAL:					

Notes:

b) Water use:

b.1) Supplied water:

Reference year:

Source	*Quantity [m^3/yr]*	*Specific Cost [€/m^3]*	*Energy consumption [kWh/m^3]*
TOTAL:			

Notes:

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

Reference year:

Water type	*Source*	*Treatment*	*Use*	*Quantity [m^3/yr]*	*Treatment specific cost [€/m^3]*
W1					
W2					
W3					
…					

Notes:

b.3) Process water analytic features:

Reference year:

Type	*W1*	*W2*	*W3*	*W4*	*W5*	*W6*	*W7*
T [°C]							
pH [-]							
Conductivity [mS/cm]							
COD [mg/l]							
TSS [mg/l]							
Hardness [°F]							
Chlorides [mg/l]							
Sulphates [mg/l]							
Sulphides [mg/l]							
Total phosphorous [mg/l]							
NO2-N [mg/l]							
NO3-N [mg/l]							
NH4-N [mg/l]							
TKN [mg/l]							
Hexavalent chrome[mg/l]							
Trivalent chrome [mg/l]							
Iron [mg/l]							
Copper [mg/l]							
Zinc [mg/l]							
Lead [mg/l]							
Cadmium [mg/l]							
MBAS [mg/l]							
BiAS [mg/l]							

Notes:

b.4) Steam production:

Reference year:

Steam type	*Water type*	*Quantity [t/yr]*	*T max [°C]*	*Use*
S1				

Notes:

b.5) Discharged water:

Reference year:

Type	*D1* (1)	*D2*(2)	*D3*(2)	*D4*(2)	*D5*(2)	*D6*(2) (3)
Quantity [m^3/yr]						
Final destination						
Features:						
T [°C]						
Conductivity [mS/cm]						
Hardness [°F]						
pH [-]						
COD [mg/l]						
BOD5 [mg/l]						

TSS [mg/l]						
TKN [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]						
Toxic Units (for algae)						
Toxic Units (for fish)						
Toxic Units (for bacteria)						
Toxic Units (for invertebrates)						

Notes:

c) ENERGY CONSUMPTIONS:

Reference year:

Source	*Unit*	*Use*	*Quantity*	*Specific cost [€/]*
Methane Gas				
Electricity				

Notes:

d) *SOLID WASTES*:

Reference year:

Type	*SW1*	*SW2*	*SW3*	*SW4*		
Description						
Waste class						
Production [kg/yr]						
Disposal						
Disposal cost[€/kg]						

Notes:

e) *OFF-GAS EMISSIONS:*

e1) Identification

Reference year:

Type	*Emission source*	*Flow rate [Nm^3/h]*	*Fumes temperature [°C]*	*Abatement*	*Abatement system*
G1					
G2					
G3					
G4					
G5					
G6					
G7					
G8					
G9					

Notes:

e2) Analytical features

Reference year:

Type	*G1*	*G2*	*G3*	*G4*	*G5*	*G6*	*G7*	*G8*	*G9*
NOx [mg/Nm^3]									
CO [mg/Nm^3]									
Aldehydes [mg/Nm^3]									
VOC [mg/Nm^3]									
Acetic acid [mg/Nm^3]									
Formic acid [mg/Nm^3]									
Ammonia [mg/Nm^3]									
Particles [mg/l]									

Notes:

f) DEPARTMENTS AND WORKING TIME:

Reference year:

Department	*Operating days*	*Daily operating period*	*Weekly operating period*	*N° of shifts per days*
General facilities				
Preparation				
Dyeing				
Finishing				

Notes:

g) EQUIPMENT:

Reference year:

Department	*Equipment*	*Item*	*Quantity*	*Operating mode*	*Bath Volume [m^3]**	*Installed power [kW]*	*Absorbed power [kW]*	*Operating years*

Notes:

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

- **An.A:** ***Material flow chart***;
- **An.B:** ***Energetic flow chart***;
- **An.C:** ***Water flow chart;***
- **An.D:** ***Production model;***
- **An.E**: ***General Facilities - Process scheme;***
- **An**.**F**: ***Preparation - Process scheme;***
- **An**.**G** : ***Dyeing - Process scheme;***
- **An**.**H** : ***Finishing - Process scheme;***
- **An.I:** ***Water consumptions;***
- **An**.**L**: ***Water discharges;***
- **An.M**: ***Discharged water analytic data;***
- **An**.**N**: ***Chemicals safety data sheets.***

Example of a Process scheme (An.E-F-G-H)

Department	
Yarn	
Process	
Equipment	
Item	
Run time (h)	
Number of run/yr	
Processed yarn (kg/yr)	
Processed yarn per run (kg)	

Water type and volume

Chemicals concenration

Steam type

bath
T=...°C
t=... min

Discharge

Discharge type and volume
T [°C]=
pH [-]=;
Conductivity [mS/cm]=;
COD [mg/l]=
TSS [mg/l]=

Water type and volume

Steam type

Warm washing
T=...°C
t=... min

Discharge

Discharge type and volume
T [°C]=
pH [-]=;
Conductivity [mS/cm]=;
COD [mg/l]=
TSS [mg/l]=

Notes: