A CASE STUDY OF LIFE CYCLE INVENTORY OF COTTON CURTAIN

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Abstract: Cradle-to-grave Life Cycle Assessment is used to estimate the potential environmental impacts, from the manufacturing to disposal of any product, process or activity. One of the main difficulties concerned with Life Cycle Inventory (LCI) is the lack of LCI data from developing or emerging countries. Production phase of textile is delocalized to these countries, and this fact has to be taken into account in the frame of a Global Production-Consumption chain. In this study, production location country is Pakistan and consumption takes place in France. Another scope is the textile product selection: cotton curtains were selected as a product to focus on diverse prospective in the production-consumption chain. Lastly, the assessment of environmental impacts consists in tracking all the inputs (including energy, water, etc.…) and the outputs of each step of the production-consumption chain. For example, major atmospheric pollutants such as CO_2, SO_2, NO_x, and other particulates, are quantified.

Key Words: LCA, CO_2 emissions, Cotton production, Curtains, Case study

1. Goal and scope

1.1. Goal of the study

Life Cycle Assessment (LCA) has been gradually implemented to a greater extent from the last two decades by many apparel and textile organizations. LCA can supply a detailed guide for identification of processes, alternates in favor of the environmental impacts and decision makings. In many study cases, LCA develops interpretations in accordance with International Standard Organization (ISO) provisions and the results are usually kept in the boundaries of an organization or a company. Also, with a recent growth in LCA work, most of the results on LCA related to textile products are limited to scientific literatures. Accordingly, there are not enough databases of Life Cycle Inventory (LCI) and open source literatures to ensemble further research studies. LCA need to take into account the impact of production delocalization to emerging countries for textile production-consumption chain.

In this study production takes place in Pakistan and the consumption takes place in France. Another scope is the textile product selection: cotton curtains were selected for the LCI flow assessment in the production and consumption phase. Lastly, the assessment of environmental impacts consists in tracking all the inputs (including energy, water, etc.…) and the outputs of each step of the production-consumption chain. For example, major atmospheric pollutants are quantified such as CO_2, SO_2, NO_x, and other particulates.

Life cycle assessment studies of different textile products have been executed focusing on certain processes. Thus, a detailed study on spinning energy has been carried out by (Kalliala & Talvenmaa, 1999). A research study on weaving process from a LCA perspective has also been carried (Koç & Çinçik, 2010).An inventory data based research for polyester textiles has been done (Walser et al., 2011). Generally, it emerged to be hard to verify the primary dataset sources because researchers and professionals construct their own dataset by merging information from confidential, diverse and some very old sources. There is a lot of textile related LCA works, but they lack in providing the complete textile processes, for instance, lack of information on the LCI data which is needed for complete LCA calculations, in-short of details concerning the production processes involved in LCA (Tobler-Rohr, 2011) and (Dahllof, 2004).

Here, the aim of the study was to identify the service and product life cycle steps having the highest environmental impacts in life cycle inventory and to prepare a future Life Cycle Assessment.

1.2. Functional unit

Functional unit is defined as: "production of a 1 kg cotton curtain and use for 10 years". It assumes that cotton curtains are washed once a season, which is the reasonable lifetime of non-apparel, textile product (SCI-Pak, 2009-2012).

1.3. System boundaries

All the processes and system boundary of this study are illustrated in Fig. 1. The processes which are considered important in the cotton production chain are as follows; (a) irrigation, agriculture, pesticides and fertilizers; (b) ginning process (c) spinning (d) weaving (e) wet-processing (f) cutting and sewing (g) packaging (h) transport. While the consumption phase includes: (a) retail in France (b) usage, washing and drying considering external factors such as electricity and detergent manufacturing, and (c) disposal, landfill and incineration.

Although the curtain comprises of 8 ring holes with steel clips for hanging purposes and a label stitched to the corner for material identification, all these articles are omitted from this LCI study. These articles are determined as insignificant to be taken in stream objectives, as already done for accessories such as buttons and collars in polyester trousers custom-made by Marks & Spencer (Collins & Aumônier, 2002).

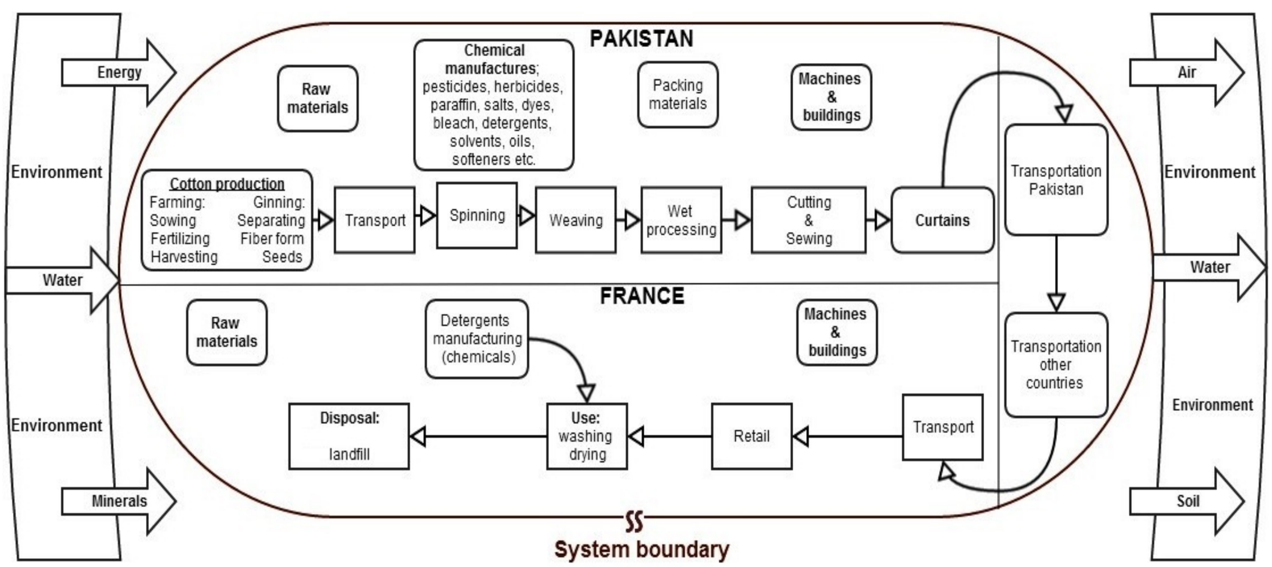

Fig.1 Graphical overview of the system boundary and the processes considered for cotton curtain production-consumption chain

2. Life cycle inventory analysis

2.1. Process flowchart

All the processes and system boundary of this study are illustrated in Fig. 2. All the inputs and outputs are taken as primary data. However, the amount of textile waste has not been quantified.

2.2. Cultivation of Cotton

When the cultivation of cotton seeds is carried out, the end products are cotton lint and cotton seeds. The inputs and outputs of Fig. 2 (a) concern both cotton fiber and cotton seeds. The cotton seed oil has been studied also, the inputs and outputs are in Fig. 3.

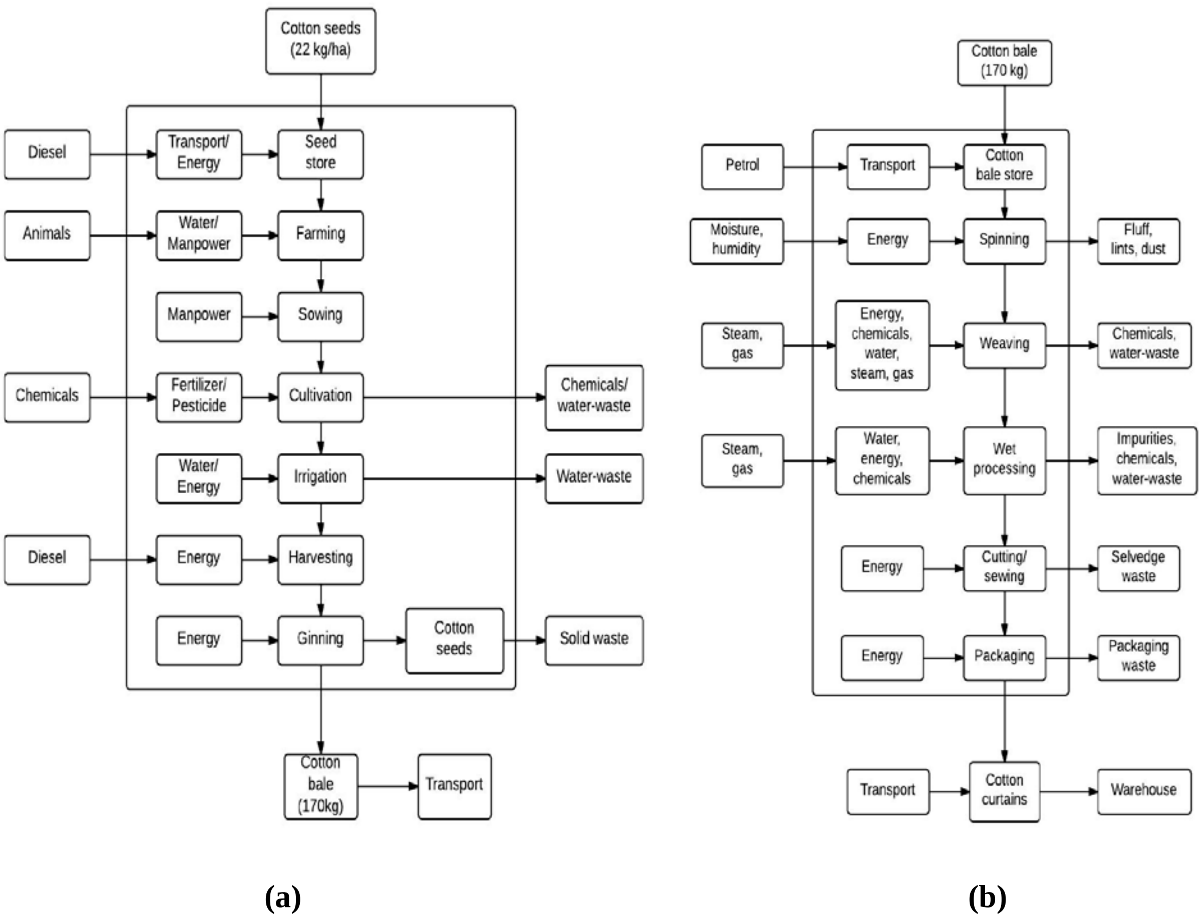

Fig. 2 Inputs and outputs of (a) cotton production and (b) 100% cotton curtain production

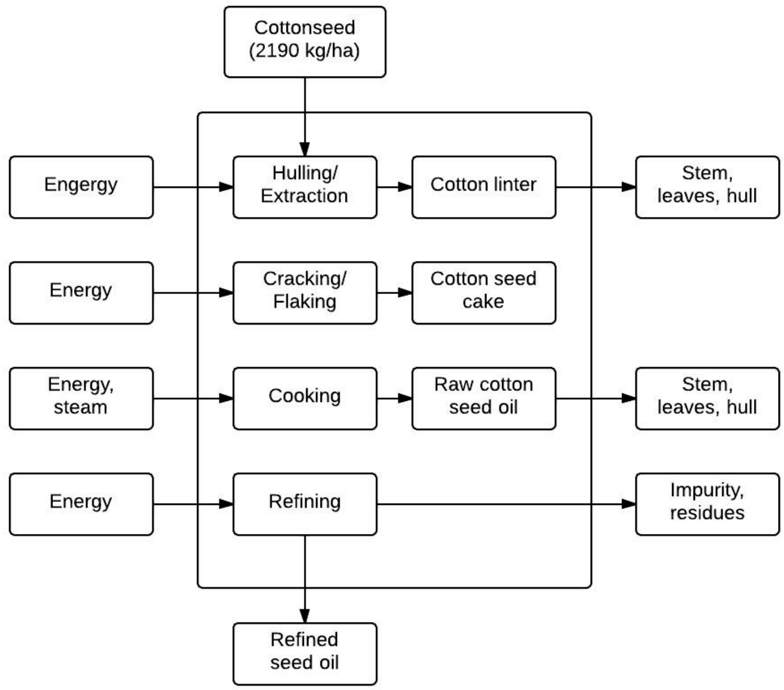

Fig. 3 Inputs and outputs of cotton seed oil production

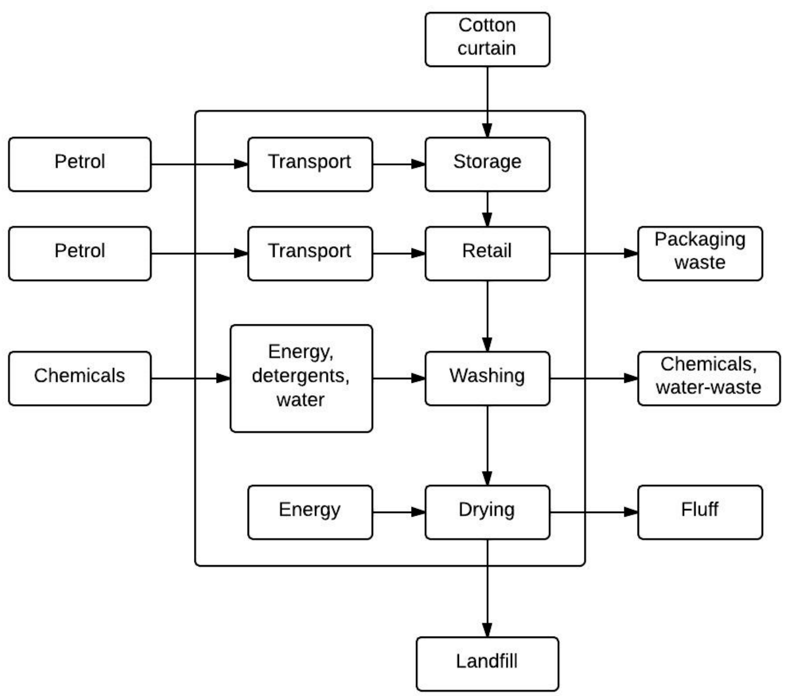

Fig. 4 Input and outputs of use phase of 100% cotton curtain in France

2.3. Data

In any LCA, approximate assumptions are made in demonstrating the product system such as; reliability of data source, wastage percentage, transportation, lifespan, etc. For the production phase of cotton curtain, this study used primary data coming directly from the manufacturer (confidential). LCA literature and other databases were also used and therefore, there is a potential degree of uncertainty in the results, as the data sources do not reproduce exact procedures. Primary and secondary data for Life cycle inventory (LCI) was gathered from the literature, textile manufacturing company and life cycle Inventory (LCI) database GaBi-6 (PE International AG, Stuttgart); primary data have been used for production in Pakistan while consumption phase was carried out by taking people`s survey interview in France.

3. Results

3.1. Cotton Curtain Production Phase

The general LCI results of four major atmospheric pollutants in production-consumption phase are illustrated in Fig. 5. The cotton production includes the processes of agriculture, irrigation and ginning etc., and also process involved in cotton seed oil production. The cotton production causes the highest pollutant emissions.

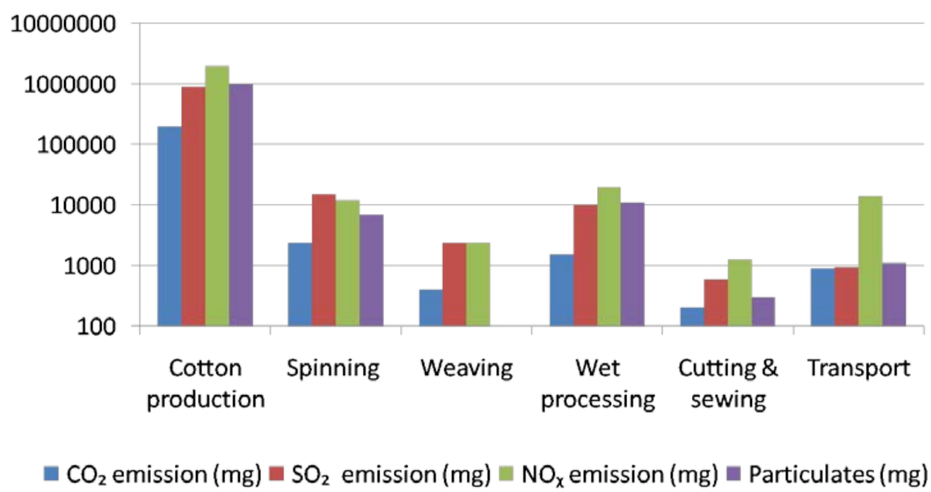

Fig. 5 Emission results of CO_2, SO_2, NO_x and other particulates taken in *logarithmic scale* for LCI elementary flow of cotton curtain production phase

From the Fig. 5, it can be seen that cotton production has the highest emission results, followed by spinning and wet processing. Indeed, spinning involves higher energy consumption of machines required in; ginning, carding and roving making, etc. In wet processing, high energy and chemical consumption such as heat drying, hot baths, dyeing and finishing etc., are involved compared to weaving, cutting and sewing which consume comparatively less energy. Transportation in production country uses diesel as a fuel, which yields higher NO_x emission values. Here transportations include, from interdepartmental to local and from factory to port for shipping.

Cotton curtains need more than 70% of energy for the production phase causing the emissions occurrence in production country. The main reason of high emissions of CO_2, SO_2, NO_x and other particulates is of processing stages, cotton agriculture and fossil fuel combustion. Another reason is lack of standardizations of emissions and improper waste treatments. The energy use contributes in particulate emissions during production of detergent chemicals, and steel tools, and during building and machinery maintenance.

3.1.1 Focus on Cotton Production (Comparison with other Production Countries)

During cotton production, the cultivation and harvesting of the cotton crop by conventional process is highly water consumptive. The emissions of pollutants are totally country dependent, as the consumption of resources and process are different in different countries China, Pakistan and India. From the Fig. 6, it can be seen easily the difference between three major textile production countries. The electricity used is nearly the same, but there is a noticeable difference in fertilizers, pesticides and water consumption.

Generally, the total water used is described as consumptive usage and non-consumptive usage to reproduce the difference in two different types of water use. The consumptive water usage is the amount of water, which is completely removed from the system by means of transpiration, evaporation or integration into a product. Meanwhile, the non-consumptive water usage is the amount of the water, which is momentarily removed from a system and returned to its sources (Torcellini et al., 2003). In hydroelectric power generation, water use is considered as non-consumptive water usage. In this study, it is not included in total water consumption. In case of cotton production, the non-consumptive water concerns only water for irrigation from rivers and ground and the sources of data are limited to "case to case studies" depending upon the cultivation seasons and year of productions. For better conclusions, latest data concerning cotton production is necessary to carry out any Life Cycle Inventory or Life Cycle Assessment studies.

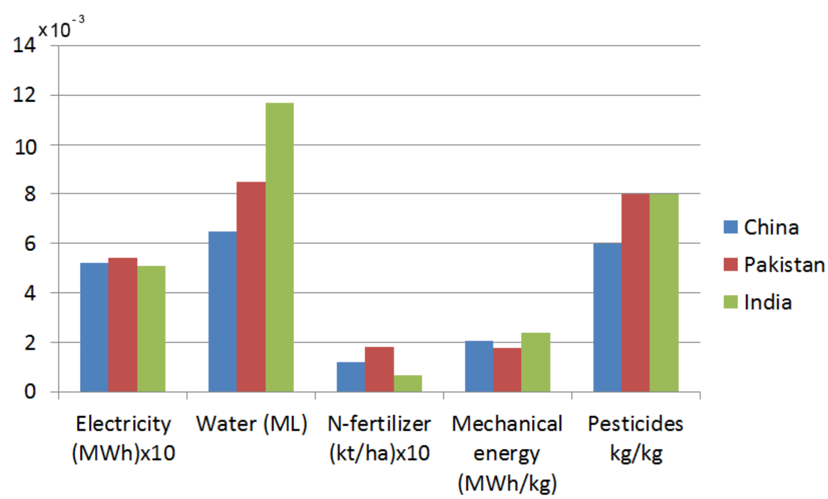

Fig. 6 Comparison of resources use among different production countries for cotton fibers

1. 'Focus on synthetic fiber to conserve water' Melvyn Thomas, TNN Nov 26, 2012, 11.12, PM IST.
2. Bluesign Technologies, AFIRM RSL Seminar presentation, September 27, 2007.
3. Reprinted in BSR, "Water Management in China's Apparel and Textile Factories," 2008.

The production of 1 kg of cotton requires 8500 liters of water and 0.5kWh of primary energy in production phase in Pakistan. The cotton production in India releases normally 5.2 kg CO_2-eq for one kilogram of lint cotton, whereas in Pakistan it goes higher to 6.5 kg CO_2-eq for one of kg lint cotton, which is due the higher usage of N-fertilizers, in India it is 66 kg/ha and 180 kg/ha in Pakistan (Moritz & Kordula, 2013).

3.2. Cotton Curtain Consumption Phase

In consumption or use phase, the washing, drying, and ironing of a textile product are the reasons of major energy consuming and of CO_2 emissions causing environmental impacts. There is a huge difference in energy consumption between production and country due to the fact for that consumption country France is self-sufficient in producing nuclear energy, while production in Pakistan majorly relies on hydropower, oil and gas. About seventy percent of energy of the production-consumption chain has been utilized in the production phase of cotton curtain. From the Fig. 7, it can be seen that, emissions from transportation are low but quite noticeable, here, transportation includes, from Belgium port to French territories and distribution of the cotton curtains.

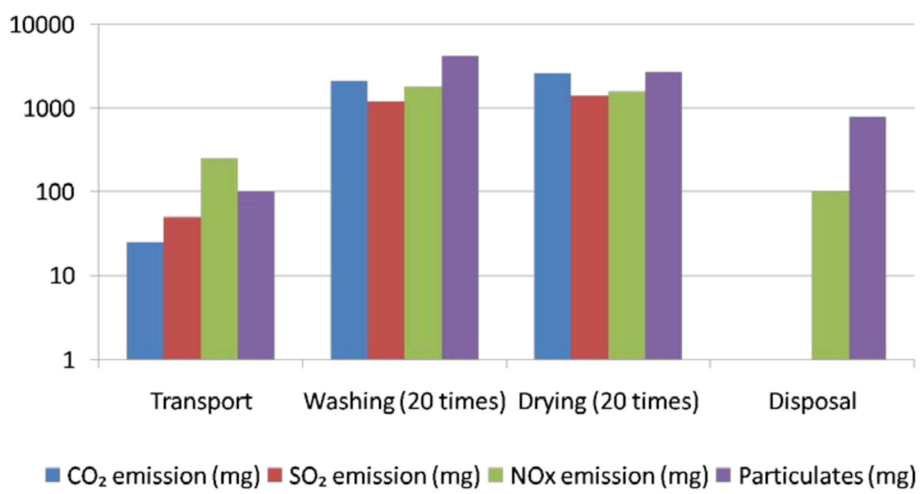

Fig. 7 Emissions results of CO_2, SO_2, NO_x and other particulates taken in *logarithmic scale* for LCI elementary flow consumption phase of cotton curtain

Disposal of cotton curtains is taken as landfill, which does not emit CO_2, or SO_2 but emissions such as NO_x and other particulates are visible, which is due the degradation process.

3.2.1 Focus on Washing and Drying (Comparison with other Consumption Countries)

The energy consumption in consumption phase is different from different data sources, from the Table 1, it can be seen that the different textile products have variant manufacturing and washing energies, depending upon individual case studies. According to (Collins & Aumônier, 2002), a cotton brief weighing about 216 grams utilizes 78.5% of its consumption energy, whereas, polyester blouse weighing 54 grams uses 2% of its consumption energy (Smith & Barker, 1995).

Table 1: Energy consumption of textile products in different countries

Textile products	Weight (kg)	Country	No. of washes	Manufacturing Energy	Washing Energy	Energy/kg/wash	Energy/kg/dry	Energy/kg/iron
Polyester Trouser[1]	0.4	UK	92	20%	61.5%	0.88%	0.46%	0.32%
Cotton Curtain	1	France	20	70%	30%	1%	0.9%	-
Men`s cotton brief[1]	0.216	UK	104	16%	78.5%	1.78%	1.71%	-
Polyester blouse[2]	0.054	USA	40	98%	2%	0.92%	-	-
Denim Jeans[3]	-	USA	104	43%	57%		0.54%	

1. Collins M, Aumônier S (2002) Streamlined life cycle assessment of two Marks & Spencer plc apparel products, Environmental Resources Management, Oxford.
2. Smith GG, Barker RH (1995) Life cycle analysis of a polyester garment. Resour Conserv Recycl 14:233–249.
3. BSR (2009) Apparel industry life cycle carbon mapping. Business for Social Responsibility.

The energy consumption and emission values in the consumption phase depend upon a number of factors such as; the number of washes and weight of textile products. As cotton curtains are washed once a season per year during a period of use of ten years, it has same energy consumption per wash as compared to cotton briefs, polyester trousers and Denim jeans.

The energy consumption in consumption phase is also “case to case” and country dependent, as the consumption of resources and machinery are different in different countries. It can be seen from the Table 1, that the average energy required for one wash is about 1% of the washing energy regardless of the textile product. Likely, any textile product which is washed less, formerly discarded immediately, will primarily have lower environmental impacts in consumption phase. According to functional units of ten years, the production phase will increase as the demand of buying a new product will increase.

The LCI of cotton curtain shows that when the environmental impacts of a textile product production-consumption chain are considered, production phase has higher impacts as compared to consumption or usage of textile product. Due to the lack of filtration implementation and emission standards, the emissions are at greater fraction in production country. In production, cotton production, spinning and weaving have higher impacts than other processes of production; meanwhile, as the curtains are washed less often than apparel textile products, they have lower environmental impacts. The consumer can alter the emissions outputs: for better sustainability management, consumer behavior is an essential factor for controlling negative impacts on the environment (Jackson, 2005).

3.3. Conclusions and Recommendations

LCI results of any textile products over the entire production-consumption chain are usually case dependent. Whenever, filtration implementation, waste treatment, emission standards, dyeing and finishing processes are included as a part of study, the emissions values gets higher.

Additionally, LCI data studies on textile products are immediately needed to minimize the uncertainties in up-to-date LCA of textile products.. Furthermore, the outcomes from this study enhance the developing body of knowledge in the global community of LCA community and can motivate other textile related industries compute their resources and decrease the environmental impacts in order to improve their products and services.

Cotton production is the process responsible for the main emissions and impacts among all processes considered in this study. An improvement in the environmental performance of cotton production depends on rationalization of the use of Agrochemicals, particularly the pesticides. Even if the fragility of the cotton crop limits the adoption of alternative methods for pest control, the chemical control should be optimized, including opting for the use of more selective and safer molecules.

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