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Greening of the Textile and Clothing Industry

Abstract
Today consumers are becoming more aware of the need to protect the environment, and companies use these terms to promote their goods or services with eco-labels. Environmentally friendly (also eco-friendly, nature friendly, and green) are terms used to refer to goods and services, laws, guidelines and policies claiming to inflict minimal or no harm on the environment. Clothing is an integral part of our lives and green or environmental concerns have started to draw more and more attention in the textile and clothing sector . This paper analysed how green the textile and clothing industry is with respect to the product lifecycle, from raw material through the design, production and logistics up to disposal in order to point out important points and parameters for greening the industry.

Key words: *green, environmentally friendly, eco-friendly, textile industry, apparel industry.*

Introduction

Globalisation results in both pressure and drivers for all countries and enterprises in the world that are trying to improve their environmental performances. Global pollution and increased awareness are prompting consumers to seek healthier living choices. 'Green' principles and strategies have become vital for companies as public awareness of their environmental impacts has increased. Today consumers are increasingly health conscious and actively support greener lifestyles. Green clothing (also known as natural clothing, eco friendly) provides consumers with healthier and more environmentally friendly apparel choices [1]. Environmentally friendly (also eco-friendly, nature friendly, and green) are terms used to refer to goods and services, laws, guidelines and policies claiming to inflict minimal or no harm on the environment [2].

Green or environmental concerns are also drawing more and more attention in academia and there are many studies in literature including the word "green". There are lots of earlier works focussing especially on green logistics and green supply chain subjects [3 - 10]. When the green textile and apparel industry is considered, it is seen that there have not been enough studies conducted in this area. Moore and Ausley presented an example to increase productivity through greener production induced by cooperative stakeholder actions [11]. Wang et al. used fuzzy logic with the analytic hierarchy process to form a selection (decision-making) model for different green initiatives in the fashion industry [12]. Wu et al. studied Taiwan's textile and apparel manufacturers and investigated the relationships between green supply chain management drivers (organisational support, social capital and government involvement) and GSCM practices (green purchasing, cooperation with customers, eco-design and investment recovery [13]. Zabaniotou and Andreou presented a paper concerning a feasibility study for energy recovery from cotton ginning waste with greenhouse gas emissions reduction in a textile plant located in Northern Greece [14]. Hashem et al. investigated a novel approach for upgrading both the wrinkle free and softness properties of cotton fabrics without adversely affecting their strength properties using eco-friendly finishing regimes [15]. Mirjalili et al. studied the extraction of dyes from weld using soxhlet apparatus[16]. Ren developed environmental performance indicators and identified the best achievable values for cotton woven products and wet processing [17]. Wrona investigated popular eco-labels used in different countries all over the world [18]. Koszewska evaluated the importance of socio and ecocertification and labelling for meeting buyers' expectations of textile and clothing products [19]. Atilgan investigated environmental regulations and their effects on the Turkish Textile Industry[20]. He also researched structures concerning eco-labels in EU countries that Turkey is aiming to integrate [21]. As a strategic solution, Eryuruk aimed to evaluate a logistic center establishment as a competitive strategy to gain advantages like time, cost and customer satisfaction for Turkish clothing producers in Istanbul, Turkey [22 - 24].

Important indicators of eco-labelling systems for textile products were studied by Nieminen *et al.* and a simple structure was developed as a base for labelling. These are energy consumption (MJ/kg) levels during fibre production, spinning, weaving/knitting, wet processing; determining transportation in km/kg, investigating raw materials in g/kg according to renewable or non-renewable, investigating water consumption in kg^{-1} (fibre consumption or industrial processing), controlling industrial emissions to air in g/kg and industrial emissions to water in g/kg, analysing the use of harmful substances (during fibre production or industrial processing), evaluating the working environment in the aspect of noise level and temperature [25].

In many previous approaches, researchers have studied green logistics and supply chain management, they evaluating a specific subject or solution for textile applications. This paper presents some of the earliest issues related to the green or eco-friendly textile and apparel industry. Moreover it is identifies and clarifies what green means and analyses the current situation in the world regarding the green textile and apparel industry. Also presents important greening parameters and analyses the textile and clothing product life-cycle with respect to green definition.

Green aspects in the textile and clothing industry

Eco friendly clothing is created from resources that are environmentally friendly and sustainable. Consideration is given to the product's total life span as well as its impact on the planet, in other words, the carbon footprint [1]. Eco friendly clothing is created from resources that are environmentally friendly and sustainable, and efficient management of obtaining green clothing requires to consider all stages, starting from designing for the environment, obtaining raw materials, producing garments, distributing them to the channels, stores and also considering their reverse logistics and waste. ***Figure 1*** shows the stages of the textile product life-cycle and environmental im-

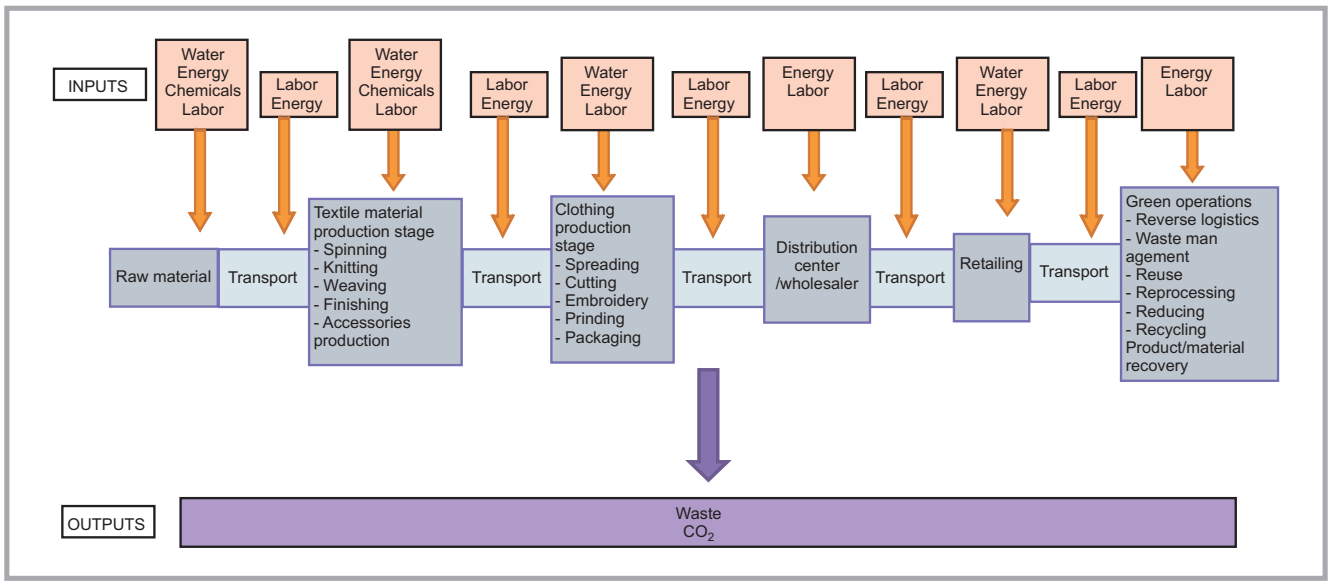

Figure 1. *Textile product life-cycle and environmental impacts.*

pacts. Along the product life-cycle there are many key inputs and key outputs that are very important in the green life-cycle procedure. Green aspects in the textile and clothing indstry will be evaluated along the product-life cycle.

Design

Life cycle assessment (LCA) is used to forecast the impacts of different production alternatives of a product to able to choose the most environmentally friendly one. Today designers must compare several different products according to several categories, such as energy use, toxicity, acidification, CO_2 emissions, ozone depletion, resource depletion and many others. By comparing different products, designers can make decisions about which environmental hazard to focus on in order to make the product more environmentally friendly [26]. This causes the minimisation of waste and hazardous by-products, air pollution, energy expenditure and other factors.

Raw material

One of the largest polluters in the world is the textile industry. At least 8,000 chemicals are used to manufacture raw materials into our clothing and linens. Seven of the top fifteen pesticides used in non-organic cotton growing methods are considered as „possible", „likely", or „known" carcinogens. According to the World Health Organization, 20,000 deaths occur annually in developing countries from the poisons in pesticides that are used in crops. Growing cotton alone uses about one-quarter of the world's insecticides [1].

Synthetic fabrics and clothing fibres processed with heavy chemical agents are facing a declining popularity because of the harmful effects on our planet and our health. Organic textiles are healthy, natural, breathable, and were grown without cancer producing pesticide and insecticide.Today many companies offer their customers products made from organic cotton, hemp, bamboo or soy fibres (***Figure 2***) [27]. Organic clothing is made from organic fibres grown without both exposure to toxins and irreversible environmental damage. Sustainable agriculture is a renewable resource, with the main idea being that the earth's natural resources are not exhausted.The focus is to have a minimal long-term effect on the environment. Key factors of sustainable clothing are the fibre source and renewability without the use of agro-chemicals, hormones, and pesticides, along the entire manufacturing process from raw fibre to textile [1].

Processing

The process of textile production involves the use of further toxic chemicals which are often bonded to the fabric fibres by use of heat. Many of these chemicals leave residues that can never be washed out. They are used for fabric treatments such as bleaching, straightening, sizing, shrink resistance, anti-static and wrinkle reduction, stain and odour resistance, fireproofing and moth-proof-

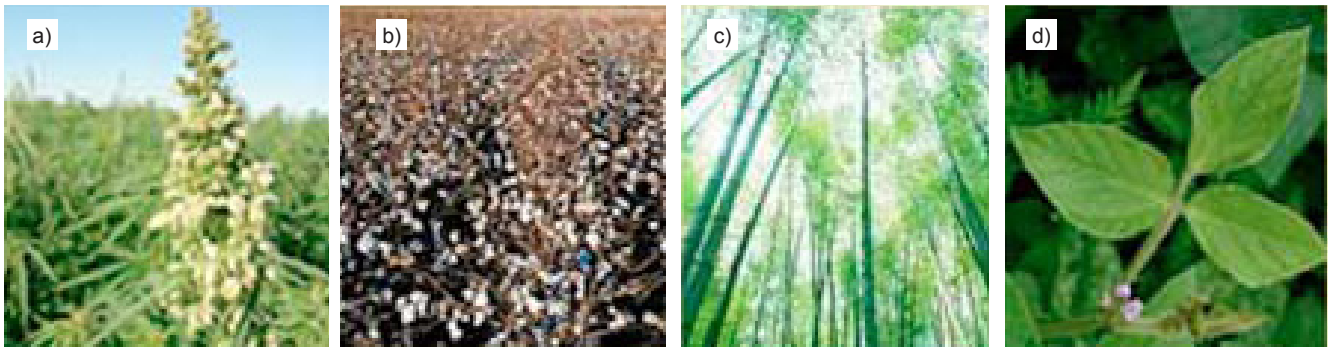

Figure 2. *Environmentally friendly fibres; a) hemp, b) organic cotton, c) bamboo, d) soy [27].*

ing, disinfectants, mildew prevention and dyes [1].

Moreover a finite source water is used at every step of the textile process, becoming full of chemicals, which in turn pollutes the environment via the effluent's heat, through its increased pH, and because it is saturated with dyes, defoamers, bleaches, detergents, optical brighteners, equalisers and many other chemicals used during the process. We breathe chemicals that evaporate into the air or are absorbed through our skin from raditionally produced fabrics that contain residuals of chemicals used during their manufacture [28].

Also packaging is very important, and the materials of which used mustt be environmentally friendly. This can be achieved through the reuse of shipping products, the elimination of unnecessary paper and packaging products, the efficient use of materials and space, the use of recycled and/or recyclable materials. The end-of-life of a product is very important because some products emit dangerous chemicals into the air, ground and water after they are disposed of in a landfill [29].

Green operations

The main application of *green operations* is improving an existing product or process. These operations include *manufacturing* and *remanufacturing* , *reverse logistics*, *network design* and *waste management*. The main goal of *green manufacturing* is to reduce the environmental impacts of a product by using proper material [30]. *Green manufacturing* includes activities such as reducing and recycling; while remanufacturing includes reusing and product/material recovery. Also green manufacturing and remanufacturing requires inventory management, production planning and scheduling besides the usual planning due to varying and unknown amounts of products returned for recycling.

Reducing is a technique in which the consumption rate of scarce materials and/or energy is minimised. *Recycling* refers to activities performed to recover material from products. *Reusing* is the concept of using intact parts of used products for manufacturing activities. *Product/material recovery* refers to activities performed to regain the product value at the end of its lifecycle. These activities include repair/refurbish and disassembly [31]. *Waste management* is the management of waste generation and its impacts through activities such as source reduction, pollution prevention and disposal. Marguglio defined waste minimisation as reducing hazardous waste generated during production and operations, and afterwards treating, storing or disposing wastes. Source reduction and pollution prevention strategies try to hinder pollution at the genration source, while disposal is intended to dispose waste after its generation [32].

Textile waste can be classified as either *pre-consumer* or *post-consumer*. *Pre-consumer textile waste* consists of by-product materials from the textile, fibre and cotton industries. This waste is recycled into new raw materials for the automotive, furniture, mattress, coarse yarn, home furnishings, paper and other industries. *Post-consumer textile waste* consists of any type of garments or household articles discarded either because they are worn out, damaged, outgrown, or have gone out of fashion. They are sometimes given to charities but more typically are disposed of in the trash and end up in municipal landfills [33]. *Textile scrap* categories can be classified as cotton, wool, jute, sisal and burlap, polyurethane foam, nylon, synthetic textile scrap, carpet scrap, rags and wipers, used and recycled bags, used clothing, used footwear, leather scrap, textile recycling employment and other textile scrap. The average lifetime of any clothing is deemed to be for about 3 years, after which they are thrown away as old clothes [34].

Reusing

There are important benefits of recovering and recycling textiles, both environmental and economical. The first advantage is reducing the need for landfill space. Certain synthetic fibre products do not decompose, while natural fibre such as wool does decompose but produces methane, which contributes to global warming. The second advantage is reducing pressure on virgin resources. This includes materials traditionally used in textiles, such as cotton or wool, as well as oil and other chemicals employed to produce synthetic fibres. Reducing pollution as well as water and energy consumption and reducing the demand for dyes and fixing agents are other advantages [35].

More than a million tons of textiles are thrown away each year, most of which by households rather than industry (***Figures 3*** & ***4***). Today many recycling centers, charities and collection projects accept textile goods. Clothing, shoes, blankets, curtains and other items made from fabric can be reused if they are in good condition, or converted into new products if they are damaged or worn [36]. Approximately 50% of all textiles collected are reused and 50% are recycled. In many African countries, over 80% of the population dress themselves in second-hand clothing. In order to see the environmental advantages resulting from the collection of used clothing, a study was conducted by the University of Copenhagen in 2008. By collecting 1 kg of used clothing, one can reduce 3.6 kg of CO_2 emissions, 6000 l of water consumption, 0.3 kg of the use of fertilisers and 0.2 kg of the use of pesticides [35].

Recycling

The recycling process starts with sorting collected textiles according to their condition and the types of fibres used. Unwearable textiles are sold to the 'flocking' industry for shredding and re-spinning. These textiles are first re-sorted according to their type and colour. The colour sorting means no re-dying is needed to save energy and avoids pollut-

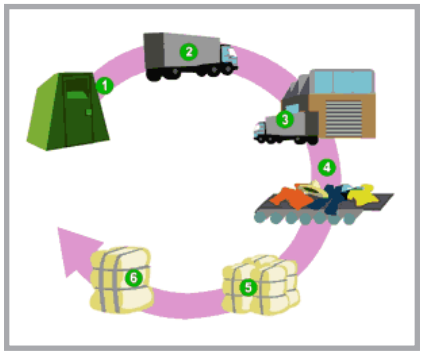

Figure 3. *Textile recycling [37].*

Figure 4. *Textile reuse [38].*

ants. Then textile materials are shredded or pulled into fibres and depending on the end use of the yarn, other fibres may be incorporated. The blended mixture is carded to clean and mix the fibres. The yard is re-spun ready for later weaving or knitting. Depending on the final application, fibres sometimes do not need to be spun into yarns; they can simply be compressed to create new textile fillings. In the case of polyester-based materials, recycling starts by cutting the garments into small pieces. The shredded fabric is then granulated and turned into polyester chips, which are are melted and spun into new filament fibres used to make new polyester fabrics. Knitted or woven woollen and similar materials are reused by the textile industry in applications such as car insulation, roofing felt, loudspeaker cones, panel linings and furniture padding. Cotton and silk is used to manufacture paper and to wipe and polish cloths for a range of industries from the automotive to the mining sector. Other types of textiles can be reprocessed into fibres for upholstery, insulation, and even building materials [35].

Green logistics

For industries with lower margins, such as the clothing industry, green supply chain management can lead to lower supply chain related costs. These cost reductions can be translated into significant competitive advantages and profit. Other benefits of green supply chain management include reducing risk, improving productivity, increasing property value, improving public image and creating healthier environments [31].

Green supply chain management (GrSCM) concepts manage environmental impacts where they occur, ideally before they occur. GrSCM tries to minimise the undesireable environmental impacts of supply chain processes within the participating organisations and the whole supply chain as well. Srivastava (2007) defined GrSCM as *"integrating environmental thinking into supply-chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the final consumer as well as end-of-life management of the product after its useful life*." [39].

Reverse logistics is also a very important concept, and Rogers and Tibben-Limbke [40] have defined reverse logistics (RL) as*"the process of planning, implementing and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal."* RL activities vary form product/industry to product industry, but common activities are collection, transportation, inspection/sorting, storage, reprocessing (including recycling, reusing, repairing) and/or disposal.

Green procurement is another subject important in the green supply chain. Burt and Pinkerton [41] defined procurement as the process of *"Deciding what,when and how much to purchase; the act of purchasing it; and the process of ensuring that what is required is received on time, and in the quantity and quality specified"*. Procurement activities include inventory management, identifiying requirements, determining requirement specifications, finding appropriate suppliers, contract negotiation and management (price, amount, quality,delivery schedules etc.), receiving, quality inspection, storage and inbound distiribution. Green procurement tries to minimise the enviromental impacts of selected products and services [31].

It is estimated that freight transport accounts for roughly 8% of energy-related CO_2 emmission worldwide. The inclusion of warehousing and goods handling is likely to add around 2 - 3 percent to this total. In the road transport sector, the amount of energy used to move freight is increasing at a faster rate than the energy consumed by cars and buses, and may overtake it by the early 2020's. Green logistics represent the several strands that are moving freight transport externalities, city logistics, reverse logistics and corporate environmental strategies towards logistics and green supply chain management [42].

McKinnon and Woodburn differentiated four levels for green logistics [43]:

1. Strategic decision relating to the numbers, locations and capacity of factories, warehouses, shops and terminals.
2. Commercial decisions on product sourcing, the subcontracting of production processes and distribution of finished goods.
3. Operational decisions on the scheduling of production and distiribution that translate the trading links into discrete freight flows and determine the rate of inventory rotation in warehouses.
4. Functional decisions relating to the management of logistical resources

Logistic activities are responsible for much of the environmental cost associated with modern retailing. Environmental effects of green logistics can be divided into six categories [44].

1. *Greenhouse gas emmission (GHG)s:* Numerous gases have a global warming effect with different degrees. Canbon dioxide is produced by burning of fussil fuels in vehicles and power generation. It is the most important GHG emitted by retailers. Also temperature control equipment releases refrigerant gases that can have a global warming potential thousands of times greater than CO_2. Some large retailers measured their "carbon footprints" , for example Marks&Spencer has estimated that its logistics activities comprise approximately 11% of its total CO_2 emissions.
2. *Noxious gases*: These gases are nitrogen oxide, sulphur dioxide and particulate matter, (PM10) affecting local air quality, human health, vegetation and buildings negatively.
3. *Noise*: This is caused by mainly vehicles and distribution centers.
4. *Accidents*: The cost of personel injury/death, any damage to property and released use of emergency services deemed to be environmental costs.
5. *Waste*: Retail logistics operations generate large quantities of waste, mainly in the form of packaging material. Products damaged or life-expired in the supply chain have to be rejected and this can also be considered a type of logistics-related waste. Today retailers must have controls for the recycling and reuse of packaging and other waste.
6. *Visual intrusion:* Many peope dislike the appearance of trucks and warehouses and they believe that they reduce quality.

The average grammes of CO_2 emitted per tonne-km for a deep sea container ship, freight train, heavy truck and long haul airfreight are around 14, 30, 80 and 570, respectively. Changing freight from air or road to rail and water-born transport can significantly decrease the retailer's footprint. Also air transport is significantly more expensive than movement by sea, but the difference in rates does not ad-

equately reflect the huge difference in environmental costs [42].

The global apparel market has been changing under the influence of many factors. One of the critical observations is that developed economies have been shifting textile and apparel production to developing economies and four major production blocks seem to have emerged as the main competitors for this shifting production capacity: China, India, Latin and South America, and Pan European and Mediterranean regions. The number of links in a supply chain and logistics activities are very important. It might consist of a single link from the distribution center to the shop or several links. Goods are transported through each link in the retail supply chain, reflecting the retailer's sourcing strategy, the geographical structure of the logistics system and the efficiency of vehicle routing. By achieving higher levels of vehicle fill, the amount of truck traffic can be reduced. In order to allow more fuel efficiency and reduce traffic congestion, deliveries must be inside off-peak periods. Converting from conventional diesel fuel to alternative fuels or to battery powered vehicles recharged with electricity (generated by renewable means such as wind or water power) can significantly cut emmissions of CO_2 and noxious pollutants [42]. H&M builds distribution centers in their international locations in order to cut down lead times and potential logistical costs. Zara has the opportunity to be one of the trendiest/low priced retailers, and one of the market opportunities for Zara is to invest in internet retailing, especially directed toward the U.S. market. Their European strategy includes having a strong production and distribution facility in their home country in order to have short production and lead times [45].

Conclusions

The aim of this study was to analyse the current situation of textile and clothing industry to increase the awareness for making it more green. The competitive environment forces industries to redesign their existing structures, and today it is an obligation to be environmentally responsible in the textile and clothing industry. In this paper, we put forward the current environmental situation of the textile and clothing industry and draw attention to important problems and parameters along the entire production life cycle from raw material to the finished products.

As a result of this study, it can be concluded that starting from the product design stage, raw material selection, to the processing and production decisions, transportation, retailing and waste management, it is possible to make textile and clothing production more environmentally friendly by taking precautions. Moreover, during recent years, how to determine suitable and green suppliers and logistics structures along the supply chain has become a key strategic consideration. A well-structured supply chain is of key importance in achieving efficient operations among suppliers, producers, distribution facilities and retailers.

In our future work, we will aim to use other sources of evidence (i.e. companies' process related data and interviews with personnel using the survey method) to obtain real world data to make the textile and clothing industry greener using the ideas expressed in this article. Then it can be used to formulate specific solutions and environmentally friendly options for greening the textile and clothing industry and obtaining constructive results.

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