Ecological demands on textiles

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Ecological Demands On Textiles

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SUMMARY

Textile industry is one of the fastest growing industries, so environmental issues are increasingly associated with it, leading to the introduction of requirements and standards to prevent further pollution. The main requirements are protection of people in the use and manufacturing of textiles, the ban of toxic and carcinogenic substances, the reduction of energy consumption and natural resources, environmental protection and proper waste management. In the past, the focus was on increasing textile production and lowering costs to the extent that seriously endangers the environment and human health. Today, there is more discussion about sustainability of textile manufacturing and developing of eco-labels, but the future holds much greater demands and introduction of new alternative raw materials and production methods.

Key words: ecology, eco-labels, environment, textile industry, sustainable design

1. INTRODUCTION

1.1. Object and purpose of thesis

The purpose of this thesis is to examine the influence of textile industry on ecology, to discuss the necessity of setting up and implementing ecological demands and standards in textile production, and, finally, to observe the impact of these demands on the situation in textile manufacture today and in the future. Throughout the thesis, I will try to explain the subject and add my personal views and ideas on the influence of ecology on textiles. The main reason why I chose this topic is the world's growing interest in ecology that will be described and explained through the thesis based on the textile industry and with my own conclusion on the observed subject. The groundwork for this thesis is the theoretical part of the course Textile finishing and the practical part consists of collecting and using appropriate literature that describes this subject.

1.2. Data sources and collection methods

The main source was the professional literature of the Faculty of Textile Technology in Zagreb, books from other sources, as well as extracts of articles published in professional journals available on the Internet. As a method of collecting data, I have used the already published studies and research, complemented with my interpretation of the subject. In order to complete the specified topic, I will significantly rely on the articles published in renowned journals in the field of textile technology by experts and professors that covered the subject.

1.3. Content and structure of thesis

The content of the thesis provides a clear view of how all the areas of the thesis will unite and cover all aspects of the subject matter. The causes of the ecological demands on the textile industry, explanation of this demands and finally their

implementation and impact, explains the subject of work and clearly describes how these demands changed the textile industry. In conclusion, I will finally bring my own views and opinion, and apply the additional knowledge gained through the development of this undergraduate thesis.

2. THEORETICAL PART

2.1. Causes of ecological demands on textiles

Ecology is the scientific study of interactions among organisms and their impact on the environment. It is an interdisciplinary field that includes biology, geography, and Earth Science [1]. Topics of interest to ecologists include the diversity, distribution, amount (biomass), and number (population) of particular organisms, as well as cooperation and competition between organisms, both within and among ecosystems.

Environmental science is an interdisciplinary academic field that integrates physical, biological and information sciences to the study of the environment and the solution of environmental problems. Related areas of study include environmental studies and environmental engineering. Environmental studies incorporate social sciences for understanding human relationships, perceptions and environmental policies. Environmental engineering focuses on design and technology aimed at improving environmental quality in every aspect [2].

Ecological issues are also present in the field of textile production. According to the European Commission, textile and clothing industry is a diverse and heterogeneous industry which covers a wide range of activities from the production of fibers and their transformation into yarn, woven, knitted or non-woven fabrics that are used to create a variety of products in demand, not only in clothing industry but also in aerospace, construction and automotive industries as well as medicine or sports. However, textile and clothing industry is among the biggest pollutants. Rapidly changing trends and the premature replacement of products contribute to the abovementioned. The question of disposal and recycling of textile waste is a growing problem in textile manufacturing. Textile manufacturing is a complex process that involves a variety of mechanical, physical and chemical processes, often very demanding in terms of energy and water consumption, the use of chemicals, as well as in relation to the employees in the production processes (noise, dust, humidity, etc.). Today, numerous institutions around the world engage in proposing solutions for sustainable production, processing and maintenance of textiles. As for consumers of textiles, most are interested in textile

harmfulness to human health, thus putting the production of textile under a magnifying glass [3].

2.2. Textile industry throughout the past

From the very beginning of humanity, there has always been a need for textiles. According to current findings, textiles were first used in the Stone Age. The first step to manufacturing processes known today were primitive sewing needles. The invention of the loom in prehistoric era represents a significant advance in textile technology. The exchange of luxury fabrics was dominant on the Silk Road, a series of ancient trade and cultural routes of transmission that were at the center of cultural interactions throughout Asia, bringing together eastern and western traders, merchants, pilgrims, monks, soldiers, nomads and urban dwellers from China to the Mediterranean Sea during different periods of time [4]. Trade routes originated in about 114 BC, during the reign of the Han Dynasty, although earlier trade across continents had already existed [5].

Before the Industrial Revolution, individual workers manufactured fabrics in their homes. The most important textile raw material was cotton, which replaced silk and wool fabrics. With mass import of cotton, manual fabric production could not keep up with the demand, so there was a need for a new method. First came spinning mills, such as spinning Jenny and spinning mule, run by water, followed by machines run by steam engines, indicating the start of Industrial Revolution. Most of the production shifted to mechanized mass production while clothing remained handmade. The next important inventions were sewing machines. Sewing machines appeared in the 19th century and allowed much faster manufacturing in factories [6].

Before the textiles were made in factories, they were made in local and national markets. Dramatic advancements in transportation encouraged the production in factories. Consumers bought cheaper goods that were produced in other places instead of local textiles because of the new advancements in transport such as steamboats, canals and railroads that lowered shipping costs. Between 1810 and 1840, the development of national markets prompted the manufacturing which tripled the output's worth. This increase in production created a change in industrial methods, such as the production in factories instead of handmade woven materials [7].

The development of factories resulted in numerous advantages and disadvantages. While effective production grew with every employee, there was a need for higher quality and lower prices of products. This resulted in the exploitation of the workforce, mostly women and children, slavery in the cotton fields and poor working conditions in the factories. Furthermore, large amounts of pesticides, insecticides and water were used for growing cotton, while simultaneously consuming large amounts of electricity, water and chemicals for textile finishing.

At the end of the 80s and 90s of the last century, textile manufacturers in developed countries were attacked by the media who criticized the environmental suitability of textile manufacturing. They were putting headlines that clothes, particularly the ones from synthetic fibers, hide many dangers to human health and "professional" books were published on the same subject without valid arguments. Consequently, there was an objective need to inform consumers about the products, their qualitative characteristics, environmental attributes and impact on human health. In the long term, manufacturers had to develop and offer products in accordance with sustainable development to remain competitive on the market [8].

2.3. Impact of textiles on ecology and society

Although the focus is no longer on lowering costs to the extent that seriously endangers the environment and human health, textile industry is still one of the biggest pollutants of the environment. Different types of operations vary in amount of pollution. In the cultivation of raw materials, the amount of pesticides that cause soil degradation and loss of biodiversity and could lead to health problems of workers is reduced [9]. Wet processes such as washing, bleaching and dyeing use vast amounts of water and wastewater is later discharged into the environment. The baths used in processing contain a wide variety of chemicals, such as formaldehyde, chlorine, heavy metals and others. Wastewater is often of high temperature and pH value, both of which can also be damaging [10].

These processes are also energy-demanding and cause air pollution. Air pollution is the most difficult type of pollution to sample, test, and quantify in an audit. Sources of atmospheric emissions vary from: using sizing compounds, high temperature

ovens and boilers and preparation, combing, carding and fabrics manufacturing. In addition to the pollution of water, soil and air, textile industry produces large amounts of solid waste, which is not necessarily hazardous. These include textile waste scraps of fabric and yarn, packaging waste, paper, cardboard, plastic packaging; dyes and chemical containers as well as general domestic waste. Frequent replacement of textiles caused by constant changes in fashion imposes a need for recycling, reusing and proper disposal of textile waste [11].

Figure 1. Life cycle of pollution [12]

All this has led to the realization that it is necessary to focus on reducing the use of energy, water and other raw materials while reducing solid waste [13]. There is a need to incorporate the principles of sustainability in all aspects of textile production, from product design (eco-design, green design and sustainable design): the use of sustainable raw materials and sustainable methods of production to final disposal of textile waste [14].

Eco-design has been defined as "the systematic integration of environmental considerations into product and process design" and aims to minimize the costs and "adverse environmental impacts of products throughout their entire life cycles" [15].

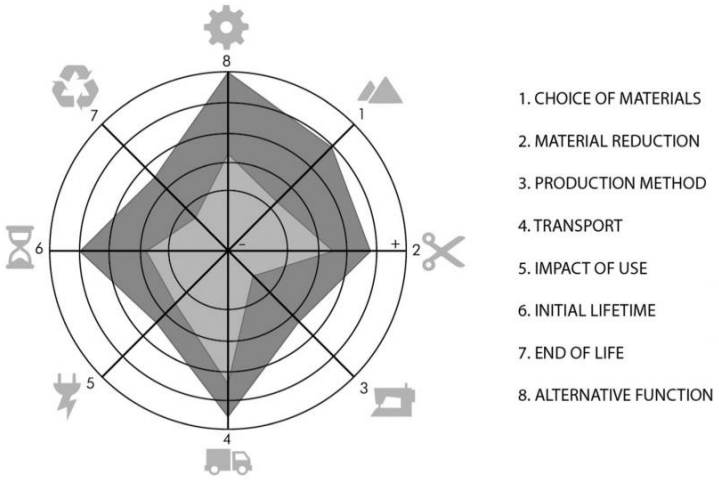

Figure 2. The Eco-design Strategy Wheel, graphic reproduction designed by K.M. Lussenburg [16]

The image above shows an example of the application of this Wheel in case of a random product. The closer the points are to the outside of the circle, the greater the degree to which a certain strategy is taken into account. The dark grey surface of the figure, representing eco-design product, is larger and scores better on all strategies than the original design (light grey). Strategies that stand out the most are the choice of materials (1), and alternative function (8), while strategies regarding transport (4) and impact of use (5) show the least improvement [16].

Sustainable design is a practice in which products that contribute to social and economic well-being have a negligible impact on the environment and can be produced from sustainable resources. Design decisions enhance the global environment and protect the world's ecosystems [17].

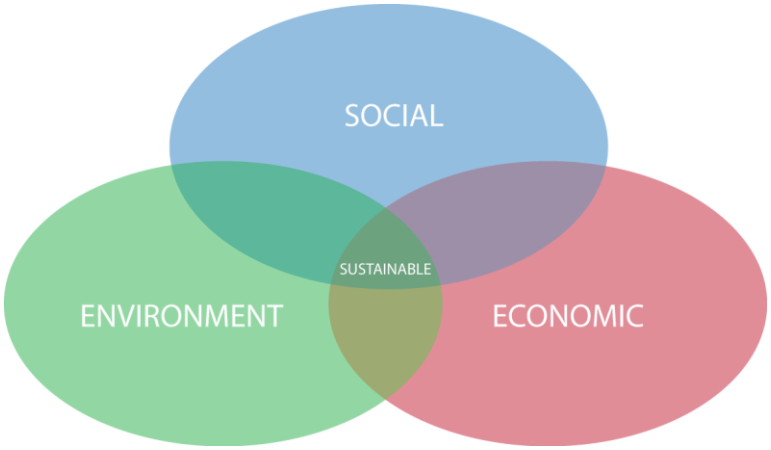

Figure 3. Components of sustainable design [17]

Green design is a term that implies environmental, health and safety analysis relevant for the entire product life cycle. The idea is to reduce the consumption of resources and the amount of textile waste during production, use and disposal or to encourage reuse of textiles. Green design is a subcategory of sustainable design that can be applied to certain environmental benefits of a product, e.g. 'recycling design'. While sustainable design refers to the practice of using products which contribute to social, economic and environmental well-being, green design refers to products which have a negligible impact on the environment and are produced from sustainable resources [18].

2.4. Reducing the ecological damage

By publishing research results in Bremen, in 1986, which proved the presence of large amount of pesticides and insecticides on cotton (especially DDT), the textile industry again came under media attack [19]. Cotton and textiles in general became number one topic in newspaper headlines, different consumer organizations, green movement and the subject of most expert discussions. Their biggest concerns were not only pesticides and insecticides, but also textile production, especially textile finishing. Even though a worldwide research on cotton conducted from 1991 to 1993 proved that the amount of hazardous substances was under control, consumers still believed textiles were harmful. Consumers' mistrust is not surprising considering the size of textile market and a very often unknown origin of cheap textiles. Their request that textiles should not only be beautiful and comfortable, but also should be completely safe and harmless is entirely justified. In order to stay competitive on the market and to convince consumers in the quality of their products the associations of manufacturers and retailers were established, along with laboratories for testing environmental product reliability and suitability of the processes, which ultimately resulted in 'eco-friendly' labels [3].

3. EXPERIMENTAL PART

3.1. Ecological demands on textiles

Ecological demands on textiles can be divided into three levels: manufacturing processes, use of textiles (which mainly focuses on human textile ecology) and recycling of textile waste. Although requirements vary depending on the region, the corresponding awareness of the consumers and the financial and technical possibilities are of great importance today.

The first sector, manufacturing processes demands (production ecology), consists of many regulations regarding the safety of textile production and the corresponding products. The focus is placed on reducing energy consumption (electricity, water, steam) and using more careful routes to finishing products [20].

The second sector, human ecology, has developed greatly with the emergence of eco-labels. They demand that finished product has no harmful effects on human health. New developments include formaldehyde-free, easy-care finishes, non halogen flame retardants, so as antimicrobial and wellness finishes [21].

The third sector, textile disposal and recycling, deals with the disposal of discarded textile products using certain techniques without posing any threats to people and the environment. The rate of waste generated is increasing with the population rate and social standards; more advanced and wealthier societies (individuals) produce more waste. It has thus become very important for manufacturers to act upon these demands and to educate consumers about ways they can help reduce waste and recycle textiles [22].

3.1.1. Production ecology

From the textile fiber to the finished product, production should not cause any harm to humans or to the environment through all the stages of manufacturing. This means not polluting the soil, air and water, reducing noise and using raw materials, auxiliary products, reducing water and energy consumption. Considering humans in

textile production, there are numerous environmental and health issues, such as working conditions and working hours, the employment of children and work safety for pregnant workers and new mothers [23].

Using raw materials that do not meet quality standards generates large amounts of waste so textile factories should not accept poor quality materials if they wish to achieve better, more efficient and faster production operations and minimize the amount of waste. Materials that remain after being used should be sorted carefully during the production and related industrial establishments should be contacted to seek ways of reusing these materials. Along with fabrics, various accessories are also used in garment construction. If the garment is categorized as ecological, the production process and all used materials should meet environmental requirements. Buttons, metals in zippers, nickel in buckles, chromium in leather accessories, neoprene-based adhesives, rubber in sponges and hooks in underwear fall in this category [24].

Due to the great amount of water used in textile finishing and dyeing, there is a need to reduce it. Depending on the technical specifications of the machines, the amount of water used for 1 kg of finished product varies between 100 and 400 L. Economizing the water usage minimizes not only water consumption but also waste management costs [25]. Table 1 shows percentage of water consumption in each process of textile production [26].

Table 1. Total water consumed during wet process

Process	Water Consumed (%)
Bleaching	38
Dyeing	16
Printing	8
Boiler	14
Other uses	24

Choosing chemicals and dyeing substances that can be effective even when used in minimum quantities could also reduce pollution. Reusing dyeing baths, using dyeing

plants and chemical substances to offset the impact of certain chemical makes wastewater less harmful. Some acidic and basic residues of substances used during the finishing process could cause a change in the pH value of the product and lead to skin irritation. To prevent this, textiles are washed and neutralized to the pH value of the human skin. Heavy metals that enter textiles through fibers and dyes, such as arsenic, lead, cobalt, cadmium, copper, mercury, antimony, nickel and chromium, have toxic effect. Due to their toxic effects, heavy metals are allowed in textile products up to limited values. Pesticides are widely used in the production of plant fibers and especially in cotton cultivation as well as animal fibers. Textile products bearing Eco-labels are supposed to contain minimum amounts of pesticide residues [27].

Machines should be designed to economize the consumption of water, chemicals, dyes and energy. It is extremely important that these machines do not reduce production quality, cause any time and labor loss and contaminate the product or the waste material due to leaking, overflowing and dripping. Therefore, it is necessary that maintenance and repair work for these machines are conducted periodically on a regular basis [28].

3.1.2. Human ecology

Demands for the quality of textile products, in order not to cause any harm to people through physical contact, respiration or digestion, are mostly related to human ecology. These include limits for potentially harmful substances and banning toxic and carcinogenic substances in manufacturing textiles. Although a few diseases associated with harmful substances from textiles were proven, like allergies and dermatitis, negative media influence further underlined this problem. In order to distance themselves from bad publicity, manufacturers have started to put eco-labels on their products. At the time they were introduced, their credibility was questioned because they were mostly used for marketing purposes and there was no institutional control of eco-labels. Today, eco-labels are clearly and strictly defined and present a true guarantee of ecological reliability. Each label has predetermined testing methods on textiles and demands for laboratories that can conduct these tests. Another important

thing is to connect eco-labels and certified quality assurance systems, such as ISO 9000 [3].

Standard ISO 9000 states three requirements that companies must meet. The first one is to achieve and maintain quality or service in a way that will permanently satisfy the identified needs of consumers. Second requirement is internal quality assurance and third is external quality assurance, which means creating consumers' confidence that the products will achieve planned quality [3].

In the European Union, the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) regulations enacted on 1 June 2007 require clothing manufacturers and importers to identify and quantify the chemicals used in their products. REACH aims to provide a high level of protection of human health and environment, to allow free movement of substances on the EU market, to enhance innovation in the chemicals industry and to promote using alternative methods for the assessment of the hazardous properties of substances. These regulations may even require manufacturers to inform consumers about potentially hazardous chemicals that may be present in their products and can leak out, which often happens with dye. Actual end products are governed by stipulations of the European Equipment and Product Safety Act, which regulates the use of heavy metals, carcinogenic dyes, and other toxic substances used in textile manufacture [29,30].

Figure 4. REACH compliant logo [30]

Additional consumer protection is offered by the Öko-Tex Standard 100, a testing and certification program. OEKO-TEX was founded in 1992 by the Austrian

Textile Research Institute (Österreichisches Textil-Forschungsinstitut, O.T.I.) and Hohenstein Institute (Forschungsinstitut Hohenstein, F.I.H.) based on a nine-year research in O.T.I. led by Professor Herzog. OEKO-TEX deals directly with humane textile ecology, testing and assessment of possible hazards of textile products for human health. The Standard 100 by OEKO-TEX gives the textile and clothing industry uniform guidance for the potential harm of substances in raw materials as well as finished products and every stage in between—these include regulated substances as well as substances that are believed to be harmful to health, but are not yet regulated. The standard also governs elements such as colorfastness and pH value [31]. Labeled products range from products underlying high standards as textiles for babies and underwear to products which have to meet less strict requirements as textiles for decorative purposes such as wall and floor coverings.

Figure 5. OEKO-TEX® logo [32]

The EU Ecolabel is a voluntary scheme designed as a marketing mechanism for environmentally safe products sold in the European Union. Applied in different product groups, it is only awarded to those products which prove to have the lowest environmental impact in a product range. The standards of the EU Ecolabel address environmental issues along the entire life cycle of textiles. They mainly embrace certain input specifications; the production needs to ensure that toxic residues in fibers are kept under the in-detail defined level. The EU Ecolabel further limits the use of specific substances harmful for the environment and human body. It addresses manufactures, importers, service providers, traders and retailers concerned with textile products [33].

Figure 6. EU Ecolabel logo [33]

The Blue Angel is one of the oldest standards, founded in 1978 in Germany, and it was built around four principles: better environmental standards in the manufacturing process, improving occupational safety and health, avoiding harmful chemical substances in the product, and good usability. The Blue Angel for textiles was released in December, 2010 on the initiative of the Environmental Label Jury and approved by the German Federal Ministry of the Environment, Nature Conservation and Nuclear Safety. The main aim of the Blue Angel for textiles is to provide reliable guidance for sustainable textiles based on environmental and consumer safety. In addition to the prohibition of certain processing chemicals, the Blue Angel for textiles sets criteria for specific product testing to minimize the danger of residues in the final product, e.g. formaldehyde, extractable heavy metals, hazardous colorants, phthalates and plasticizers, polycyclic aromatic hydrocarbons (PAHs), chlorophenols, organotin compounds, chlorinated benzenes and toluenes or dimethylformamide [34].

Figure 7. Blue Angel Standard logo [34]

Such regulations and standards, coupled with increasing consumer awareness of less toxic and sustainable products may provide some impetus to revolutionize the garment industry. However, the largest environmental impact of textiles occurs when they are being used by the consumer: the use of electricity to heat water and run laundering and drying processes. Using detergents that work well at lower temperatures, extending the usable life of garments, purchasing fewer and more durable garments, and recycling these garments into the used clothing market or into other garment and non-garment products all contribute to increasing sustainability. Consumer awareness of the fate of clothing through its life cycle may be the best hope for sustainability in the fashion industry [31].

3.1.3. Textile disposal and recycling

In recent years, textile production and consumption have risen drastically due to global population growth and improvements in living standards. Over-production in the textile industry is partly driven by the idea behind the fashion industry that consumers need a new clothing collection for each season. This increases the rate of replacement of products and the rate of textile and waste generation [35].

Textile waste disposal demands are focused on the possibility of recycling the waste and its return to the production process, with the remanufacturing, or an environmentally acceptable destruction. Also, these procedures must be sustainable, so the utilization of energy and water must be kept to a minimum and should not pollute the environment.

Reducing material at the source should be the starting point. Manufacturers themselves must reduce the amount of materials they use, either raw or for packaging, and conduct activities that increase product durability and reusability. With all that, they will pass less waste material to consumers who often improperly dispose of waste. The aim should also be changing consumer habits with an objective of reducing at the source (not buying unnecessary textile and products in general). Ways of reducing at the source and recycling are shown in table 2 [36].

Table 2. Cleaner production techniques

	Technique	Description
Recycling	On-site recycling	Re-entering the waste into the process as a substitute for an input material, as byproduct, as raw material for other processes (within the same factory)
	Off-site recycling	Recycling process is done by specialized company, to industrial waste or at the post-consumer stage
Reduction	Technology change	Replacing old process with one that is less energy consuming and more efficient
	Input material change	Substituting materials with less harmful ones, more feasible to use, with same or better technical requirements
	Better process control	Good control of the operating parameters
	Equipment/process modification	Improving process and account for more efficient utilization of raw materials, water, energy, reducing emissions to the environment
	Product modification	Changing the product design to use less raw materials and energy, or to minimize emissions

The following method in waste managing is reusing. This means that the material continues to be used in its original form or slightly modified, for the same or different purpose (tin cans for holding paint brushes), but without remanufacturing or recycling. Reusing is closely connected with reducing. This technique could be applied by consumers and manufacturers, because reusing at the same time reduces waste at the beginning of the process. Source reduction and reuse are the best options in waste management since they preserve natural resources by reducing pollution and the need for new landfills or incineration [35].

As far as recycling is concerned, it is a less preferred option in waste management. All waste that cannot be reduced or reused goes to recycling, where it is processed into raw material to produce a new product. Well-guided systems of recycling, ones not doing more harm than good; can be a major investment and require additional skills. Therefore, recycling is often transferred to third world countries, where a large number of factories are located. A positive thing is the involvement of governments in making regulations under which factories are required to have certain recycling systems [35].

Recovery is a procedure similar to recycling. Both processes are based on waste collection and processing for the purpose of further use in manufacturing. The difference is that recycling does not need special processes to sort waste, it is classified manually, while the recovery waste is collected as mixed refuse, and then various processing steps remove the materials. At the end, this material could be sold to another factory or put back into the production process of the same factory [35].

When consumers decide to give up their garments, they have a number of choices: discard, sell, or donate to collectors of used textiles such as charity organizations, municipalities, retail collectors or professional collectors. Until recently, discarded textiles were either incinerated or landfilled together with municipal solid waste. The donated or sold textiles are nowadays sorted and sent afterwards for reuse or recycling plants depending on their quality. Most of the textiles which retain high quality are sent to East European or African countries for reuse and the remaining flow is sent to recycling plants. Since only a few different methods for textile recycling exist today, the majority of the flow is downcycled into wipes, rags or is used as insulation in different industries. The remainder of the collected used textiles is either landfilled or incinerated. In some cases, clothing which is no longer in use is accumulated in closets

or exchanged informally between friends or family members. In 2013, only 25% [37] of the textile waste generated in the European Union was collected by charity organizations or industry enterprises with the purpose of reusing or recycling. The rest was sent to landfills or municipal waste incinerators. Currently, the lack of practical technologies for recycling various types of fibers limits the potential for applying recycling techniques. However, a few small-scale recycling schemes have been implemented, with the aim of producing recycled fibers. By recycling, companies can achieve larger profits because they avoid charges associated with dumping in landfills, while at the same time contributing to goodwill associated with environmentalism, employment for marginally employable workers, donations to charities and disaster areas [38].

The EU nominated textiles as a priority waste stream and in December 2008, the EU legislated on textile recycling in the form of a revised Waste Framework Directive (WFD). The Directive 2008/98/EC, determines some basic waste management principles: it requires that waste needs to be managed without endangering human health and harming the environment, and in particular without risk to water, air, soil, plants or animals. EU Member States adopted waste management plans and waste prevention programs and applied these regulations by prioritizing them according to the following waste management hierarchy [38]:

Figure 8. The EU Waste Management Hierarchy [39]

According to Ekström and Salomonson, in 2011, the Swedish fashion chain Lindex offered their costumers more than 300 000 articles made of recycled materials

as a part of a long-term commitment towards a more sustainable development. Their goal was to create a cycle of materials with fiber recovery and to help reduce the need for new raw materials in the manufacturing of new articles [40].

Pre-consumer waste consists of by-product materials from the textile and fiber industries that are re-manufactured for the automotive, aeronautic, home building, furniture, mattress, coarse yarn, home furnishings, paper, apparel, and other industries. Post-consumer waste is defined as any type of garment or household article made from manufactured textiles that the owner no longer needs and decides to discard. These articles are discarded either because they are worn-out, damaged, outgrown, or have gone out of fashion. They are sometimes given to charities. Sustainable textiles are passed on to friends and family, but additionally they are deposited in the trash and end up in the municipal landfills [41].

The reuse and recycling of discarded textiles has several potential environmental benefits. For example, reusing textile and clothing products results in energy savings, since the amount of energy required for collecting, sorting and reselling second hand garments is 10 to 20 times less than for the production of the same products from virgin materials [42].

4. RESULTS AND DISCUSSION

4.1. Impact of the ecological demands on textiles

In textile production, there are increasingly visible changes of ecological demands on textiles. Manufacturers use more organic materials, natural dyes and recycled textile waste. As consumers became more sensitive to environmental concerns and the impact of chemicals on their health, the manufacturers were forced to make changes, so there is more monitoring of production and quality. Eco-labels were introduced to the consumers as a guarantee of the quality of textiles and their production.

Today there are more norms and standards which differ from country to country, but with certain uniformity and minimum criteria to be fulfilled. Fashion designers also greatly effect positive changes in textile production since the use of eco-friendly textiles changes the attitude of the public towards the impact on the environment. Consumers themselves should be concerned because households are also highly polluting the environment with textiles. The biggest problem was created by rapid changes in fashion trends, inexpensive and easily available clothing that were thrown away. Fashion designers are now trying to change the trend by supporting the production of small quantities of textiles of higher quality and higher prices so that it is profitable to implement alternative procedures for finishing textiles and to use eco-friendly raw materials. Eco-friendly production can be extremely profitable if manufacturers clearly state it in their promotional campaign and if they are stationed in that product niche. Socially responsible production is not only concerned with the environment but also with the employees in textile industry, since the majority of textile production takes place in Asia, with low wages and poor working conditions. Therefore, it is necessary to create safe conditions for workers and fair wages in relation to working hours.

The future brings new research, more natural materials and innovation in production processes. There will be more requirements and demands, consumers will be more informed about the products and their awareness of the environment will be more expressed. It is expected that there will be positive changes in organic production, workers' rights and reducing pollution.

4.2. Demands in action

It is visible that demands on textiles are increasingly present in all processes of production, from breeding raw materials (cotton, wool, etc.) to dyeing and finishing textiles. Textile manufacturers seek alternative production methods, which are environmentally friendly and try to reduce waste and excessive consumption of energy and water. These methods include growing and using organic cotton, dyeing of textiles with natural dyes, textile finishing techniques that include nanotechnology, eco-finishing (e.g. enzymatic finishing), high performance finishing (e.g. plasma treatment), finishing with CO_2, microencapsulation, etc. [43].

As mentioned before, in order to reduce the use of chemicals and pesticides, organic cotton is now more widely grown and used. According to the Organic Trade Association, organic cotton is grown using methods and materials that have a low impact on the environment. Organic production systems replenish and maintain soil fertility, reduce the use of toxic and persistent pesticides and fertilizers, and build biologically diverse agriculture. Organic cotton is grown without the use of toxic and persistent pesticides and synthetic fertilizers [44].

Recently, most of the commercial dyers and textile export companies have started revisiting maximum possibilities of using natural dyes for dyeing and printing of different textiles for the targeted market niche. Natural dyes produce very uncommon, soothing and soft shades as compared to synthetic dyes. On the other hand, synthetic dyes, which are widely available at an economical price and produce a wide variety of colors, sometimes cause skin allergies and other harmful effects on the human body, produce chemical hazards during their synthesis and release toxic chemicals. The word "natural dye" covers all the dyes derived from the natural sources like plants, animals and minerals. Natural dyes are mostly non-substantive and must be applied on textiles by the help of mordents, usually a metallic salt, having an affinity for both the coloring matter and the fiber [45]. The most common natural dyes are: Madder, Cutch, Cochineal, Weld and Indigo. They all come from plants except cochineal, which comes from an insect [46].

Appropriate and standardized dyeing techniques must be adopted for successful commercial use of natural dyes. Not all natural dyes are safe, some are quite toxic [47].

For example, Indigo is a skin, eye and respiratory system irritant so proper health and safety equipment must be applied when working with it. It is also possible that some pesticides, herbicides, etc., may have been used on the crop or perhaps the crop itself may have been genetically modified. Also, natural dyes require more energy in the dyeing process because they usually require high temperature baths for longer periods of time than the optimized synthetic dye. The amount of natural materials, such as plants, lichens, insects and minerals, needed to color the fabric is much greater than required by synthetic dye materials [46]. Ideal solution would be to use waste from various industries, such as food, forestry or agricultural activities for the production of natural dyes. The problem of environmental pollution would be reduced significantly and production cycle would be closed [48].

Figure 9. Natural dyes [49]

The use of finished textiles, especially those in contact with human skin, has developed greatly with the use of eco-labels. Well known examples are limited values for concentrations of free formaldehyde and the corresponding test methods in connection to easy-care finished textiles. Meanwhile, low formaldehyde finishes are standard and guaranteed by most producers. Novel and new developments include formaldehyde-free, easy-care finishes. Another example is provided by novel flame retardants, which do not contain antimony and halogens. The narrow path between high

performance and safe ecology with antimicrobial finishes shows interesting results [50-51].

Best demonstration of recycling and waste management is displayed by the companies that develop consumer awareness about recycling. There are various initiatives where retailers give discount in exchange for clothes that consumers do not use, which the customers can use for buying new clothes in their stores, whereas their old clothes goes to recycling. This creates a cycle that reduces waste and develops the awareness of consumers about the impact of waste on the environment. There are also companies that are trying to cut costs, so often choose to recycle clothing, where it is cost-effective, instead of constantly buying new raw materials for production. This measure reduces costs and gives a clear message to consumers that they care about the environment and thus gain their trust, which generates even more profits. Nowadays, there are also landfills for storing textiles that go to recycling and charities in every developed country and city.

4.3. Textile industry today

Industries on a global basis should decide to modify their technology and production process in order to have an environmentally friendly output to satisfy their customers' needs. Textile industry is committed to producing eco-friendly textiles in order to face global competition. Any textile product, which is produced in an eco-friendly manner and processed within eco-friendly limits, is marked as eco-textile. Using organic fabrics is not the only way the fashion industry is going "green" and protecting the future of our natural resources. Companies are also becoming more ethical and using fair trade and fair labor. This means that companies are paying the fair price, creating fair employment opportunities and developing a safe work environment. In addition, they are "engaging in environmentally sustainable practices, making sure that product quality is maintained, honoring cultural identity as a stimulus for product development and production practices, offering business and technical expertise and opportunities for worker advancement, contributing to community development, building long-term trade relationships, and being open to public accountability" [52].

Both recycling fashion and organic clothing can contribute to eco-sustainable development.

Many companies understand the importance of being eco-friendly, not just from a "feel good" perspective, but also because it is profitable to do so. By using products that are energy efficient, costs are lowered and profits are improved, which makes stakeholders happy. In his book "Green to Gold" [53], Andrew Winston explains the necessity to cut back on energy and material consumption and generation of waste in order to reduce air and water pollution. Being eco-friendly builds brand loyalty, improves corporate reputation, and is profitable, too.

4.4. Expectations on textiles in the future

The textile industry and demographic factors will play a key role in trendsetting. As a result of continuous population growth on Earth, there will be greater pressure on land, fresh water, oil, minerals and other non-renewable natural resources which will become more depleted. Growing population means more customers, more consumers and more pollutants. Already more than 14 000 people die each day because of lack of clean, fresh drinking water so we will have to reduce freshwater consumption and pollution. We will also have to reduce chemical and energy consumption and find new ways of producing them. The only sensible way to reduce textile consumption whilst remaining economically viable is to have lesser quantities of higher quality textiles at higher prices and turning textile recycling into a mainstream practice [54].

Whereas eco-industry is developing, the main responsibility for developing environmental awareness lies in designers and clothing manufacturers. They should begin to use more sustainable materials and processes. There is a growing interest in eco-friendly clothing and this topic is addressed on a daily basis. Some manufacturers started promoting eco-friendly production as a new business concept. Also, well-known designers are slowly turning to organic production rather than using synthetics that harm the environment [52].

Textile industry faces inevitable challenges in the future. One of them is replacing cotton with other materials because of the huge amount of cotton used every

day. Another important thing is to find solutions on how to produce synthetic fibers without increasing the yield of oil. Nowadays, there is a huge trend of production of bio-based textiles from biomass or some other renewable feedstock [55].

In addition, the demand for textiles has been growing sturdily during the last decade and the worldwide annual consumption has reached approximately 73 million tons. The expected growth rate is three percent per year. Consequently, there might be a greater demand for recycled textile fibers in the future [39].

In this great step forward, it is not only the fashion world to prop the chart, it is also us who have to take the initiative. For this, we have to recycle clothes and make them useable in a reversible manner. This will increase the life of clothes and eliminate the pressure on the farmlands to grow huge amounts of cotton using harsh chemicals [10].

To recycle successfully, consumers must embrace the overall system, where it is not enough just to make an occasional charitable donation. Meanwhile, companies must continue to develop new market values and after-use possibilities so the system functions at full capacity and with commitment from all.

5. CONCLUSIONS

Taking into consideration the long history of textile industry and the fact that it is one of the oldest industries, it is important to study its development and impact on the environment. Primitive production in the past took place in private homes with textiles that were available in the area. When demand exceeded supply, factories with automated production were developed. Because of the availability and low cost of cultivation, cotton became the most important raw material for the production of textiles.

Considering that textile manufacturing was one of the most polluting industries which greatly affects the environment, there have been various attempts at reducing pollution [56]. Textile companies seek to reduce the use of water and chemicals, thereby reducing the cost of production and pollution. On the other hand, consumers tend to buy clothes of well-known origin and quality that ensures no harm to human health. Various institutions regulate environmental pollution on the market and bring different standards and demands for textile production, which encourage environmental awareness and provide correct information to consumers.

Textile waste is most commonly caused by a rapid and constant change in fashion. Therefore it is important to incorporate the principles of sustainability in all aspects of textile manufacturing. Firstly, it is necessary to reduce the consumption of water, electricity, chemicals and waste accumulation. Secondly, it is necessary to start from the design of products including eco-design, green design and sustainable design that support the use of sustainable raw materials and methods of production to final disposal of textile waste.

In order to stay competitive on the market and to convince consumers in quality of their products, associations of manufacturers and retailers have been established together with laboratories for testing environmental product reliability and suitability of the processes, resulting in 'eco-friendly' labels. Ecological demands are separated into three different categories: manufacturing processes, human ecology and recycling of textile waste. They vary depending on the region, awareness of the consumers, financial and technical possibilities and are of great importance today.

Demands in manufacturing processes are mainly focused on reducing energy consumption, such as electricity, steam and water. Also, production should not cause any harm to the environment or to humans through all the stages of manufacturing. This means not polluting the soil, air and water, reducing noise and ensuring better working conditions by refraining from children employment and protecting pregnant women and new mothers.

Demands in the second sector mainly focus on human ecology which was developed greatly with the emergence of eco-labels. Their general demand on textiles is not to cause any harm to humans through physical contact, respiration or digestion, including imposing limits on potentially harmful substances and banning toxic and carcinogenic substances. The Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) aims to provide a high level of protection of human health and environment and to allow free movement of substances on the European Union market. These regulations require clothing manufacturers and importers to identify and quantify the chemicals used in their products. OEKO-TEX, founded by the Austrian Textile Research Institute (Österreichisches Textil-Forschungsinstitut, O.T.I.) and Hohenstein Institute (Forschungsinstitut Hohenstein, F.I.H.), is dealing directly with human textile ecology, testing and assessment of possible hazards of textile products for human health. One of the most popular standards is OEKO-TEX Standards 100 which gives guidance for the potential harm of substances in raw materials, finished products and every stage in between.

Ecological demands in the third sector, textile disposal and recycling, deal mainly with certain techniques of managing waste without posing any threats to people and the environment. The EU Directive 2008/98/EC [57] requires that waste should be managed without endangering people and water, air, soil, plants or animals.

Due to growing public pressure and new standards and requirements in production, textile manufacturers are slowly turning to eco-friendly textile production. This increases their competitiveness on the global market and satisfies their customers' needs. It is achieved by various methods in the production such as growth and use of organic cotton, natural dyes, eco-friendly and high performance textile finishing. An extremely important step in reducing pollution is reducing textile waste. One of the positive examples is the investment of textile firm Olimpias Group (Benetton family); located in Croatia, through the EU project Wasatex [58]. Company has opened the first

European water treatment plant capable of recovering up to 100-percent of the dyeing plant processed water.

Companies seek to reduce waste through recycling, careful selection of raw materials and rewarding consumers who bring textile waste for recycling. With all the above mentioned, it is also necessary to take care of employees, improve production with new machines and contribute to the community development. All this can help textile manufacturers increase their profits and to get consumers' confidence in their products.

With increasing population and increasing demand for textiles, future production and pollution reduction will be even more demanding. There is also a risk of greater exploitation and lack of natural resources. It will be necessary to introduce new alternative raw materials and production methods. The only way to achieve these goals is to reduce the volume of production and begin to produce small quantities of high quality clothing at higher prices. Thereby, users will appreciate their own clothes and they will not throw it away carelessly. Designers and clothing manufacturers will have to use more sustainable materials and processes.

Nowadays, there is more discussion about sustainability of textile manufacturing, so eco-friendly production is gaining its popularity. Even some well-known designers are slowly turning to organic or bio-based production rather than using the materials that harm the environment. It is important to find ways to reduce and replace excessive exploitation of the land by growing cotton. Not only manufacturers and designers have to make major changes to reduce environmental pollution, but also the consumers themselves. They should be responsible when disposing of their clothes. Also, they should significantly increase recycling of textiles and reduce seasonal changes that are responsible for huge amounts of textile waste and excessive buying of new clothes. There should be more projects and promotional offers that will warn consumers to be aware of textile waste and encourage them to properly dispose of and recycle their clothes.

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